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Copepods Parasitic on the Fishes Collected on the Coast of Province Shima, Japan

(*With Ten Text-figures*)

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As concerns the parasitic copepods occurring on the fishes in the Province of Shima, good many species including new ones have heretofore been recorded. After my previous report (1959) dealing with the collection in our University went to press, lots of specimens were obtained on the coast of the Province. These materials together with the new forms left untouched on that occasion are dealt with in the present paper, which comprises the full descriptions of three new and one known species, supplementary notes upon two other known species and the records of occurrence of six known forms.

Genus *Caligus* MÜLLER

Caligus productus DANA

DANA 1852, U. S. Explor. Exped., 13, Crustacea II: 1354-1355, Pl. 94, Fig. 4; SHIINO 1959b: 14-20, Figs. 6-8. Refer to SHIINO 1959b for the synonyms and further bibliography.

Occurrence: Taken on the outside surface of *Katsuwonus pelamis* (L.) at Hamazima by myself, July 1959.

Specimens: One ovigerous and two non-ovigerous females and three males (No. 536). Females measure 4.8×1.8 (ovigerous), 4.7×1.9 and 4.5×2.0 respectively (all in mm). In formalin, their carapace pale yellowish brown in central region, whitish in lateral regions and spotted with darker brown pigment markings all over the surface. Males measure 4.9×2.1, 4.2×1.9 and 4.6×1.8 respectively (all in mm). They are colored as females, but tinged with yellowish brown in posterior two thirds of genital segment.

Caligus coryphaenae STEENSTRUP et LÜTKEN

STEENSTRUP and LÜTKEN 1861, Vid. Selsk. Skr., Nat.-Math., 5: 360-362, Pl. 4, Fig. 7; SHIINO 1959b: 2-8, Figs. 1-2; 1959a: 334. Refer to SHIINO 1959b for further bibliography and synonymy.

Occurrence: Found on the body sides of *Coryphaena hippurus* L. (No. 528) and of *Katsuwonus pelamis* (L.) (No. 573, new host), at Hamazima by myself, July 19, 1959.

Specimens: No. 528; one female and two males. The female 7.2×2.6, with egg strings 9.7 long, and the males 4.9×2.4 and 4.7×2.3 respectively (all in mm). No. 537; a single male, measuring 6.0×2.9 (in mm). Body yellowish brown in formalin in all specimens and with darker carapace ribs.

Caligus quadratus SHIINO

SHIINO 1954, Bull. Jap. Soc. Sci. Fish., **20**: 26–29, Fig. 1; 1959b: 8–14, Figs. 3–5. Refer to SHIINO 1959b for the synonyms.

Occurrence: Obtained on the body surface of *Rhinobatus schlegelii* (MÜLLER et HENLE) (now host) at Hamazima by myself, July 22, 1959.

Specimen: One female without ovisacs (No. 535), 5.2×1.8 (in mm), whitish in preservative.

Caligus latigenitalis SHIINO

(Fig. 1)

SHIINO 1954, Bull. Jap. Soc. Sci. Fish., **20**: 21–25.

Occurrence: Collected on the body surface of *Mustelus manazo* BLEEKER (No. 532, new host) and *Rhinobatus schlegelii* (MÜLLER et HENLE) (No. 534, new host) at Hamazima by myself, July 22, 1959.

Specimens: No. 532; two females each with a single egg case. Color in formalin yellowish brown, with brown pigment spots on genital segment. Larger female 4.40 in length, carapace 2.72×2.40, fourth thoracic plus genital segment 1.28×1.44, abdomen 0.44×0.56. No. 534; a single female with a pair of empty egg cases. Color in formalin yellowish, with fine, irregular, brownish patterns thickly covering all over the surface; eyes brown. Total length 4.28, carapace 2.72×2.40, fourth thoracic segment 0.11×0.61, genital segment 1.11×1.39, abdomen 0.47×0.54. (All the measurements in mm)

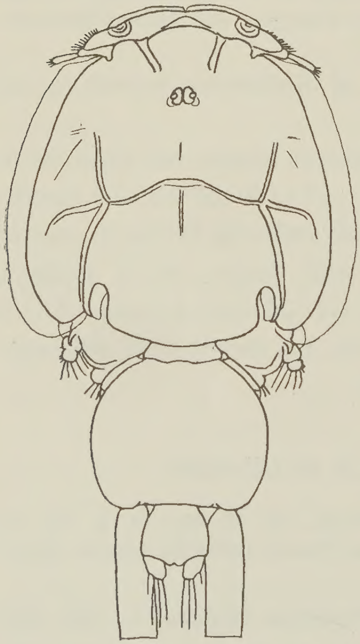

Fig. 1. *Caligus latigenitalis* SHIINO, female. ×16.8

This species known only from the female was originally obtained from *Sparus macrocephalus*. As the genital segment was accidentally somewhat compressed antero-posteriorly in the holotype, the whole view of the animal is given here anew based on the female from No. 534. Both the lots of specimens from No.

532 and No. 534 are in perfect accord with the holotype in every detail of the other body parts and of the appendages.

The diagnosis of this species, therefore, ought to be amended with respect to the constitution of the genital segment as in the following:

Genital segment broad, broader than long, convex on either side and gradually narrowing forward to form gracefully curved shoulders. Its posterior margin nearly straight, ending laterally in well round corners.

Caligus dasyaticus RANGNEKAR

(Fig. 2)

RANGNEKAR 1957, J. Univ. Bombay, **25**, Pt. 5: 16–18.

Occurrence: Obtained on the external surface of *Dasyatis akajeii* (MÜLLER et HENLE) at Hamazima by myself, July 20–21, 1959.

Specimens: Three females with egg sacs, one female without these, another with narrower genital segment, two juvenile females with narrowest genital segment, and three males (No. 530). One of the males was seizing a juvenile female with its second maxillipeds.

The species has hitherto been known from the female alone. The present collection fortunately includes the males, which will be described below.

Female: Body pale yellow in preservative, darker in color in the central region of carapace and in the genital segment, and with dendritic brown patterns on the carapace in its median lobe as well as in the posterior part of its lateral lobes and on the lateral parts of each of the succeeding segments. Eggs pale yellowish brown. Total length in the largest female 6.00, carapace 3.00×3.11, fourth thoracic segment 0.61×0.72, genital segment 1.61×1.42, abdomen 0.78×0.56, egg case 4.50 (all in mm).

The female was precisely described and accurately figured by the original author. The largest female in the present collection is about one and half times as large as the holotype. It has the fourth thoracic segment, which is not so strongly narrowed forward as in the holotype, and the genital segment which is relatively a little longer. Differing from what are found in the holotype, the line of border between these segments and the same between the genital segment and the abdomen are entirely obliterated. In spite of such differences, this female is in strict accordance with the holotype in the structure of other portions of the body and in every detail of the armature of the appendages.

As shown in RANGNEKAR's illustrations (1957, Fig. 1), the terminal spines on the first thoracic legs, the basal hook on the exopodite of the third legs and the spines, with which the two distal segments of the fourth legs are armed,

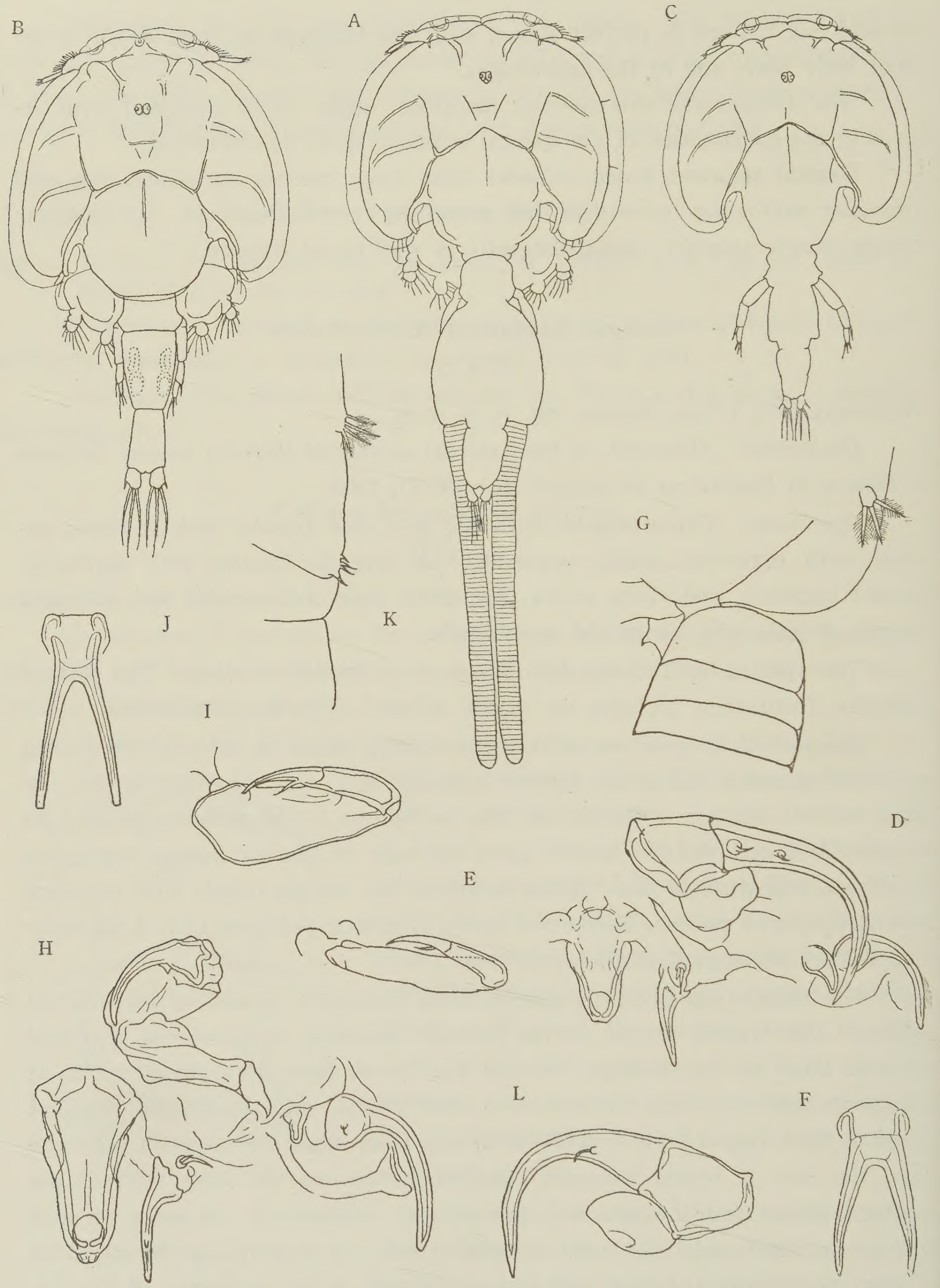

Fig. 2. *Caligus dasyaticus* RANGNEKAR. A, female, dorsal view; B, male, dorsal view; C, juvenile female, dorsal view; D–G, female; D, second antenna, maxillae and mouth tube; E, second maxilliped; F, sternal fork; G, caudo-lateral angle of genital segment, ventral view; H–K, male; H, second antenna, maxillae and mouth tube; I, second maxilliped; J, sternal fork; K, side of genital segment, ventral view; L, second antenna of a juvenile male. A ×10.8; B ×21; C ×12.6; D–G ×43; H–J, L ×85; K ×125.

are all doubly edged with unusually broad rim which shows fine parallel striations on the surface. The second antennae and two pairs of maxillae are all slender, elongate and well curved like a sickle. In all of these points the females in my hand agree with the holotype. The first maxillae are associated just inside their bases with a much shorter accessory spine which was not described by the original author.

Male: Allotype. Color in preservative as in female. Total length 2.89, carapace 1.74×1.91, fourth thoracic segment 0.23×0.43, genital segment 0.51×0.34, abdomen 0.43×0.24 (all in mm).

Carapace as in the holotype, the female, narrower anteriorly than posteriorly. Fourth thoracic segment wider than long and a little narrower than a quarter of carapace width; two sides parallel except for having a pair of triangular lateral projections at posterior end, from which the legs arise. Genital segment longer than wide, as wide at the anterior end as the preceding segment, from which it is distinctly bordered by a straight, horizontal boundary. Lateral margins nearly straight and posteriorly a little convergent toward each other. Abdomen slightly shorter and narrower than genital segment, somewhat enlarged in its width backward, and ending in a V-shaped caudal end. It is one-segmented and distinctly bordered from the foregoing segment.

Second antennae relatively feebler than in female and somewhat differently shaped; first joint a transverse ridge, second joint erected over the ventral surface, directing antero-ventrally, and third joint elongate, sickle-shaped and folded back over the second to form a sort of subchela. First maxillae proportionally stouter than in the other sex, well-curved like a sickle and with a round base, on which they bear a tubercle surmounted by a fine spinule. As in the female, they accompany a short inner accessory process which is somewhat feebler and blunter. Second maxillae resembling those of the female, but more or less slenderer and with a tiny secondary spine at a short distance from the apex. Second maxillipeds have the palm somewhat more swollen than in the female and with a round protuberance near its base, against which the end of terminal claw acts. Two branches of sternal fork slender, straight, diverging in a V-shape and truncate at their apices. Fifth legs represented by four short plumose spines issuing from an inconspicuous tubercle present on the ventro-lateral edges of genital segment a little behind the middle of its length on both sides. Sixth legs are four simple hairs present on either side close to the postero-lateral angle of the same segment. Terminal spines of caudal rami relatively longer and stouter than those of female. Otherwise as in that sex.

Juvenile female: Total length 4.10, carapace 2.48×2.38, fourth thoracic segment 0.43×0.62, genital segment 0.67×0.57, abdomen 0.55×0.38 (all in mm).

Postero-median lobe of carapace trapezoid in form and extending farther posteriorly than in the adult. Fourth thoracic segment with wavy lateral margins. Genital segment narrower than the fourth, somewhat wider than a fifth of carapace width, and only a little longer than wide; nearly quadrate, but forming a short, narrowed waist at posterior end. Abdomen a little shorter and narrower than the preceding segment and slightly diminishing in width backward.

Juvenile male: Not much different from the adult in the measurements of the parts. The second antennae different from the adult constitution and closely resembling those of the female.

Remarks: This is the first discovery of the male form and belongs to the first record of the species from Japan. Originally, the species was recorded from the Indian waters.

Caligus spinosus YAMAGUTI
(Figs. 3 and 4)

YAMAGUTI 1939, Vol. Jubil. Prof. S. YOSHIDA, **2**: 445-447, Pl. 14, Figs. 4-8.

The present species which has been known from the female alone was rather briefly described by the original author.

Occurrence: On the gills of *Seriola aureovittata* T. et S. taken at Simakatu by my son, April 1, 1958.

Specimens: No. 475, one female on unknown host. No. 515, twelve females and a male.

Female: Body relatively thick dorsi-ventrally; pale yellowish brown in formalin, without pigmentation. Total length 5.15, carapace 2.19×2.24, fourth thoracic segment 0.57×0.76, genital segment 1.71×1.24, abdomen 0.76×0.52, egg string 2.93 long (all in mm).

Carapace circular, widely round on either side and with relatively broad lateral flanges. Frontal plate half the entire width; lunules round, close to each other and accompanied just inside with a short spinule; marginal flange relatively broad. Horizontal rib of H-shaped dorsal suture arched forward and placed a little behind the centre of carapace. Anterior halves of longitudinal ribs divergent forward; posterior halves curved inward. Median lobe angular at lateral corners and fused with the succeeding segment; lateral lobes broad. Lateral sinuses deep, oval in shape, closed posteriorly and with inner and outer accessory membraneous flanges along the outer border. Eyes at the centre of the anterior area of carapace.

Fourth thoracic segment one third as wide as carapace, widest on the level passing through the limb bases and constricted both in front and behind. In front of the anterior constriction, the segment again broadens to join the carapace. Genital segment is four fifths as long as carapace, three quarters as

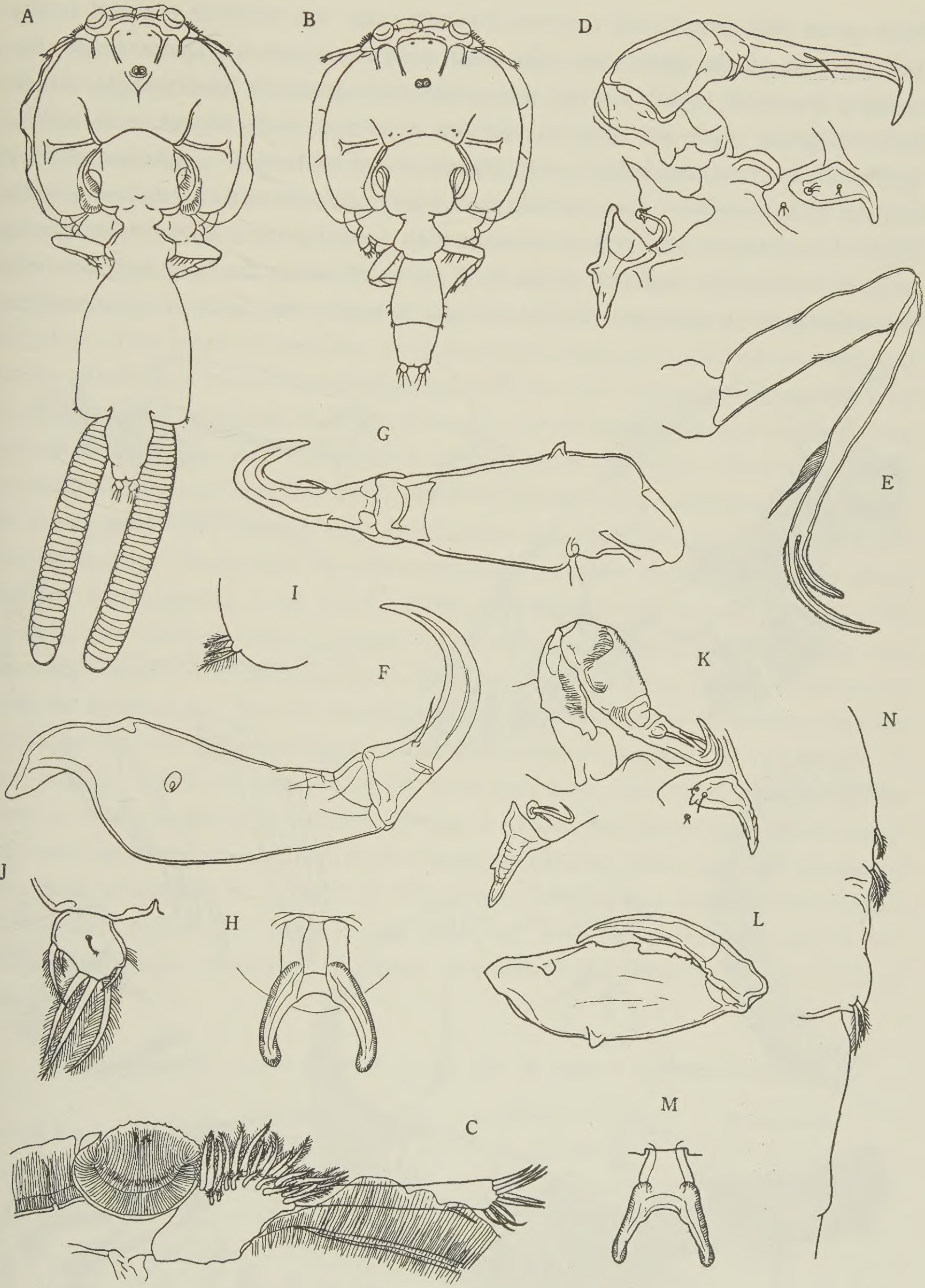

Fig. 3. *Caligus spinosus* YAMAGUTI. A, female, dorsal view; B, male, dorsal view; C–J, female; C, first antenna; D, second antenna and two maxillae; E, first maxilliped; F, second maxilliped, posterior view; G, same in ventral view; H, sternal fork; I, caudolateral angle of genital segment, ventral view; J, caudal ramus; K–N, male; K, second antenna and two maxillae; L, second maxilliped; M, sternal fork; N, lateral margin of genital segment, ventral view. A, B ×12.6; C–H, K–N ×75; I, J ×110.

wide as its own length and narrows forward until its width is reduced to the half of that of the hind end. Showing a more or less triangular shape, the segment has very widely curved sides and nearly truncate hind margin, which makes together with the side an angular corner at each lateral end, and is fused both in front and behind with the adjoining segments. Abdomen shorter than half the length of the preceding segment, longer than wide, widest a little behind the extreme fore end, narrowing both forward and backward, and with a slight constriction in front of the hind end, indicating the boundary between the constituent segments. Caudal margin truncate, but with a slight median

Fig. 4. *Caligus spinosus* YAMAGUTI, female legs. A, first leg; B, apical spines of same; C, second leg; D, armature on first endopodite joint of same; E, third leg; F, two rami of same, inner view; G, fourth leg; H, spine on same. A, C, E–G ×75; B, D, H ×305.

notch.

First antennae relatively long; distal segment slender, elongate, attaining one and half times the length of the proximal, and tipped by sharp bristles besides carrying a solitary hair a short distance back the apex; proximal joint of rhomboid shape, fringed by two rows of plumose spines; outer row consisting of longer spines, while inner row of much shorter ones. First joint of second antennae horizontal and furnished with a short blunt posterior process; second joint columnar as usual; third joint much elongate, strongly curved at the apex and carrying two spinules, one at the base and the other at some distance distally. Two pairs of maxillae small in size in relation to that of the antennal pairs. First pair have triangular base, bearing two tubercles surmounted by short hairs, and terminate in a short, blunt, curved apex. On the strenum just behind this pair on either side is a similar hairy tubercle. Second pair are conical, attenuating toward the tip, which is rimmed by a membrane resembling an arrow-head; they bear a very short inner branch about the middle of their entire length. Rudiments of their exopodites consist each of two very short and an incomparably long hairs. First maxillipeds are slender; distal joint ends in two unequal claws, fringed by narrow, pectinate membrane along two opposite borders, and carries a short distance back the apex a narrow, elongate, striated membrane. Second maxillipeds are powerful; palm is swollen near the base and has a short unguiform process on posterior surface in the region of the largest width; terminal claw is thick and long, but hardly reaching the base of palm, is strongly incurvated like a sickle, and bears a short accessory hair near its base. Sternal fork is composed of squarish base and two divergent branches, which are incurvated at the apices, interposing a semicircular median sinus; each branch is blunt at the apex and with finely striated, narrow external rim which, encircling the apex, extends to the inner border for a short distance.

Table I. Details of the armature of the legs of *Caligus spinosus* YAMAGUTI.

Leg	Border	Sternal plate	Protopodite		Exopodite			Endopodite		
			I	II	I	II	III	I	II	III
I	outer inner		1p 1p		1rh C	4H, 1rh 3P				
II	outer inner	f	 1h, 1P	f, 1s f, 1s	f, 1H c, 1P	1H c, 1P	2H, 1Q c, 5P	c, C 1P	c c, 2P	c c, 6P
III	outer inner	f	f, 1p 1P, f, 2s, c		1H′, c, 1h c, 1P	c, 3h c, 4P		 1P	c c, 6P	
IV	outer inner		1s		2s, 1H	1H	3H			

Endopodite of first legs relatively large in size and tipped by two tiny spinules. First endopodite joint of second legs strongly expanded outward. Two rami of third legs closely adjoining each other and covered at their bases by a crescentic expansion of basal apron. They are both two-jointed, though the basal joint of endopodite is strongly reduced. Fourth legs four-jointed; first joint wide, gracefully curved on outer margin, and last three joints separated one from another by obliquely running border. Armatures on those pairs of legs are diagrammatically shown in Table I.*

Of four terminal, non-plumose spines on the first legs, the onter- and innermost ones are simple, while the central two bifurcate at their apices; the outer three of them are finely serrated or pectinated along their axes and accompanied each at the base by an oval, radially striated lamina. A very tiny spinule arises from a tubercle present close to the base of the spine second from the outside. Outer short spine on the second joint is accompanied by a basal lamina. The first endopodite joint of the second legs carries on its outer margin a row of sharp, regularly arranged spinules which is followed by more proximal row of finer hairs. Outer spines on the first two exopodite joints of the same legs and the most basal of the outer spines on the third joint are finely pectinated on two opposite borders; the spine on the first joint is associated with basal lamina; the second spine on the third joint has a broad outer membrane with entire margin and an inner pectination. The basal apron of the third legs bear on its surface just outside the submedian longitudinal rib of either side a round elevated area, surmounted with a number of short blunt protuberances, near the hind end of that rib two conical processes, and extending from the base of the exopodite forward a longitudinal band of fine short spinules. Basal hook on the exopodite sharp and strongly curved in a semicircle. All the spines on the fourth legs are bordered along two opposite sides with very finely pectinated rim and accompanied each at the base by an accessory lamina with somewhat stronger pectination. Apical spines are graded in length from the inside to the outside and the middle member of them is about as long as the spines on the succeeding segments. Fifth leg rudiments are represented by three short, plumose spines located at the postero-lateral angles of the genital segment; posterior two of them arise from a small common tubercle.

Caudal rami are small in size, irregular in outline and tipped by three

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* Abbreviations in Tables: B, adhesive pad; C, row of cirri; CC, area covered with cirri; c, row of hairs; cc, area covered with hairs; f, membraneous flange of joint; H, stouter simple spine; h, feebler simple spine; H′, hook-like spine; P, stouter plumose spine; p, feebler plumose spine; Q, spine hairy on one side, with a membrane on the other side; rh, rudimentary spinule; s, solitary hair. Roman numerals represent the numerical orders of legs or of joints, arabic numerals the numbers of spines or of setae present on them.

long plumose spines. They carry, in addition, two much shorter, but unequal spines of the similar structure at the outer distal angle, another at the inner distal angle, a row of short hairs on the distal half of the inner border, and a shorter spinule on the surface.

Male: Allotype. Coloration as in female. Length 3.76, carapace 2.14×2.14, fourth thoracic segment 0.48×0.55, genital segment 0.72×0.57, abdomen 0.48×0.48 (all in mm).

Carapace as in female, but indistinctly bordered from fourth thoracic segment. The latter more or less trapezoid in shape, relatively narrower than in female, a quarter as wide as carapace, as long as broad, widest in the region through the bases of legs. The segment narrows forward to form at the extreme anterior end a short neck, which is demarcated from the main portion by a slight constriction, and is also contracted at the posterior end into a short waist which is distinctly bordered from the succeeding segment. Genital segment one third as long as carapace, longer than wide, trapezoid in shape; two sides converging forward, showing a slight curvature, and posterior border distinct and truncate. Abdomen two thirds as long as the previous segment, which it resembles in its shape, though tapering backward instead of forward. It is as long as wide, truncate on caudal margin and has a pair of slight lateral notches, representing the boundary between fused segments, behind the middle of its length.

Distal joint of first antennae relatively somewhat longer than in female. Basal joint of second antennae short, with corrugated surface and lacking in posterior process; second joint slenderer than in female, with two corrugated bulges near the base and with another corrugation on anterior side; apical joint relatively shorter than in female, but more strongly curved and provided with two basal spinules. First maxillae with apical hook longer than in female and more or less wrinkled on either edge; their base furnished with a short rudimentary accessory branch at the inner angle. Second maxillae as in female, but with the striated surface and feebler accessory branch. Second maxillipeds less powerful than in female; their palm armed along antero-internal border with a number of low conical protuberances in addition to the one on posterior side; claw not so strongly curved as in female. The branches of sternal fork not incurvated, but extending diagonally backward. Fifth legs represented by two short plumose spines issued from a papilla present on each side of genital segment a short distance away from the posterior angle, and by another similar spine placed just in front of these. Sixth legs are another pair of two spines located at the postero-lateral angles of the same segment. Otherwise as in female.

Remarks: The females of the present collection are in full accord with

YAMAGUTI's description and figures except for two points, that the body is relatively larger in size and that the genital segment has nearly straight lateral borders, which end angularly at posterior corners. The sole female from No. 475 is about the same as the holotype in the body size and similar in the configuration of the genital segment, which is somewhat better round on the sides than in the females of No. 515, but has the posterior margin not so well curved as in YAMAGUTI's. The segment is emarginate on the caudal margin rather than widely round. In other points, the female of No. 475 is in complete agreement with the same sex of No. 515 as well as with that of YAMAGUTI. There can be found no essential differences which verify the specific separation of them.

In the outline of the genital segment, in the structure of the appendages around the mouth, in the same of the fourth legs and in the armature on the basal apron of the third legs, *spinosus* is closely allied to *tenax* HELLER and *spinosurculus* PEARSE. There is a certain probability that they may be conspecific. Judging from the descriptions given by WILSON (1913) and KIRTISINGHE (1937), the male of *tenax* differs from that of *spinosus* in the absence of the boundary between the genital segment and the abdomen, in spite of a great resemblance in the outlines of both of these segments to the corresponding regions of Japanese specimens. YAMAGUTI pointed out the affinity of *spinosus* to *lunatus* WILSON which is parasitic on the same host as that of No. 515, but the male of the latter reported by WILSON (1937) from *Seriola dorsalis* in Panama Bay is entirely different from the present one in the possession of the two-segmented abdomen. BRIAN (1935) recorded *C. lichiae* BRIAN which is closely allied both to *tenax* and to *spinosus*. Although there may be some doubt whether or not they are distinct one from another, we cannot deduce any conclusive evidence as to this point from BRIAN's rather brief description, or from his somewhat rough figures. The present record represents the first discovery of the male of *spinosus*.

Caligus laticaudus n. sp.

(Figs. 5 and 6)

Occurrence: On the inner surface of the operculum of *Pagrosomus major* (BASILEWSKY) taken at Hamazima by myself, July 20, 1959.

Specimen: One female with a single egg case, no male.

Female: Holotype. Body white in preservative, genital segment pale yellow owing to the eggs enclosed within, eye vivid brown and eggs yellow. Length 3.51, carapace 1.57×1.83, fourth thoracic segment 0.17×0.57, genital segment 0.91×0.83, abdomen 0.71 long, first segment 0.39×0.45, second segment

0.32×0.36, egg string 2.45 long (all in mm).

Carapace about as long as wide, narrower anteriorly than posteriorly; sides widely round, with broad marginal membrane and with a short hair hehind the middle. Frontal plates half as wide as carapace, very widely curved on margin; adhesive lunules semicircular, widely apart from each other, placed at either end of the plates and accompanied inside by a short hair. Median lobe crescentic, reaching back beyond the linguiform lateral lobes. Longitudinal dorsal ribs widely divergent both forward and backward; transverse rib dividing the carapace exactly into two equal halves, arched forward and continuous at

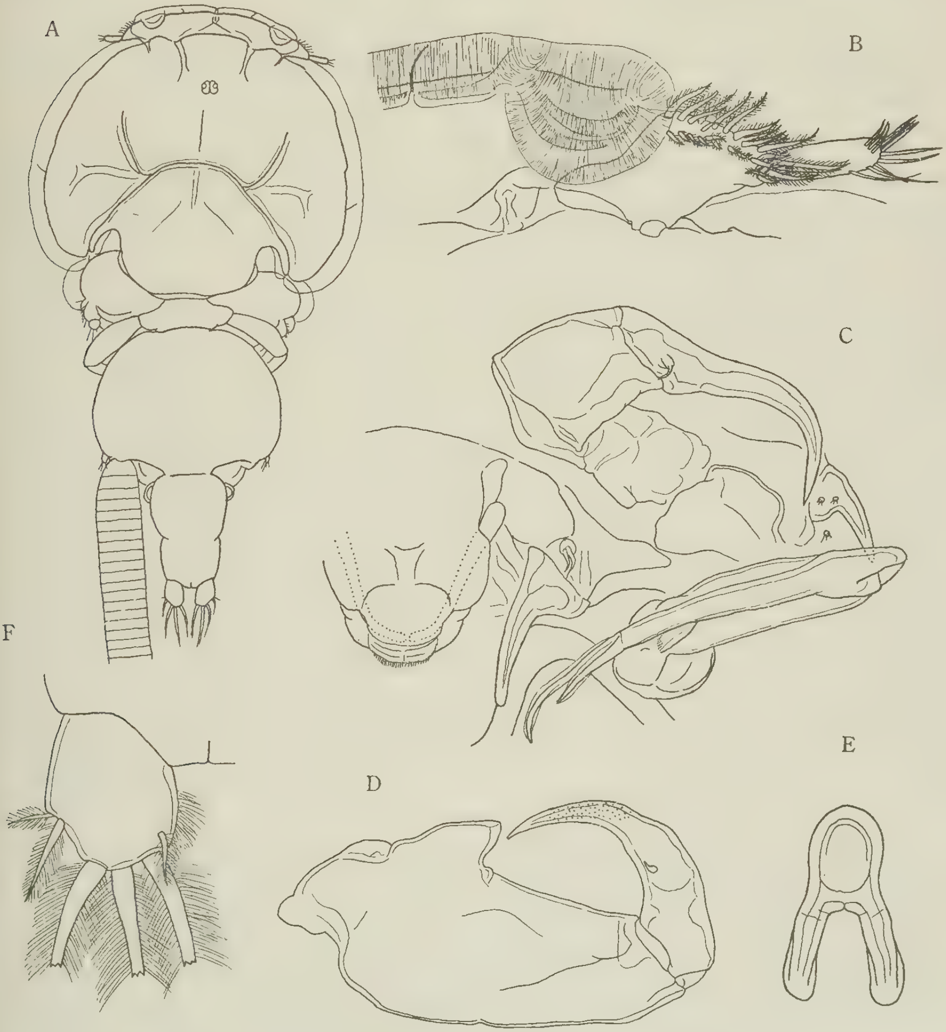

Fig. 5. *Caligus laticaudus* sp. nov., female. A, dorsal view; B, first antenna; C, second antenna, two maxillae, mouth tube and first maxilliped; D, second maxilliped; E, sternal fork; F, caudal ramus. A ×22; B–F ×120.

either end to the posterior longitudinal rib. Lateral sinuses widely open in the rear. Eyes closer to the fore end of carapace than to the central rib.

Fourth thoracic segment short and narrow, one third as wide as carapace, same time as long as its own width, contracted both in front and behind, and obliquely truncate at the bases of the legs. Genital segment semicircular; two sides forming together with the fore border a continuous arch; hinder border reentrant on either side on dorsal level, but bulged rearward on ventral level. Abdomen relatively large in size, somewhat shorter than the preceding segment, broad, two thirds as wide as long in its widest region, and somewhat narrowing backward. It is composed of two segments of subequal length, which are demarcated from each other by lateral notches and indistinct surface groove. First segment widely curved on the sides, while second segment nearly straight and ending in a V-shape.

First antennae usual in structure; basal joint rhomboid, fringed with two rows of plumose spines; apical joint short and tipped by a number of simple stiff hairs. Second antennae stout; first joint lacking posterior process, second joint short, columnar, and third joint slender, elongate, curved like a sickle, sharp at the apex and carrying at the base a short hair issued from a tubercle. First maxillae short, acuminate at the apex resembling a bird's beak, and oblong at the base, which carries two tubercles surmounted by a few tiny hairs. On the sternum just behind each of the first maxillae there is another similar tubercle. Second maxillae better developed than the first, being composed of triangular base and more or less curved, slender apex with blunt end. Endopodite in front of their base consists of two short hairs. Mouth tube broad. Terminal joint of first maxillipeds slenderer, but longer than basal joint and ending in two unequal claws edged with rims. Second maxillipeds robust; palm well swollen, longer than the distal joint of the first maxillipeds and bearing an enormous triangular bulge on inner border near the base; claw stout, sharp, strongly curved, acting upon the bulge of palm, granulated in apical portion and carrying a tiny spinule for some distance apart from its base. Sternal furca has oval base and two divergent branches, which are rimmed with flattened membrane in terminal region and end in blunt apices.

First thoracic legs have a blunt rod-like rudiment of endopodite which is tipped by a tiny spinule. Joints of second legs ordinary in structure. Exo- and endopodites of third legs separated from each other by the insertion of a large crescentic expansion of basal apron. Both of them two-jointed; first joint well-developed, longer than the second in the exopodite, whereas much reduced in the endopodite. Fourth legs thick and composed of four joints; first joint as long as the rest three combined together; these latter bordered one from another by oblique lines. Spines and hairs with which four pairs of the thoracic legs

Table II. Details of the armature on the legs of *Caligus laticaudus* sp. nov.

Leg	Border	Sternal plate	Protopodite		Exopodite			Endopodite		
			I	II	I	II	III	I	II	III
I	outer inner		2s, 1p		1h c	1h, 3H 3P				
II	outer inner	f	1s 1P	f, 1s f, 1s	f, 1H c, 1P	1H c, 1P	1h, 1H, 1Q 5P	 1P	cc c, 2P	cc 6P
III	outer inner	f	f, 1p 1P, f, 2s, c		1H′, c, 1h 1P	c, 3h 4P		 1P	c 6P	
IV	outer inner		1p		C, 1H	C, 1H	C, 3H			

are ornamented are diagrammatically listed in Table II.

All of the terminal spines on the first legs simple, unforked and without marginal rim. External spines on the exopodite of the second legs sharply pointed, with or without pectinate rim; third of the external spines on the apical joint relatively short, blunt, fringed with inner row of hairs, but without outer membrane. Basal hook on the exopodite of the third legs blunt at its apex and rimmed on the outer side with a very narrow crescentic plate. Last three joints of the fourth legs fringed along outer border with a row of short spinules which extends from the inner distal angle of the fourth joint to the point a short distance behind the end of the second joint. Spines with which this pair of legs are armed are doubly edged with narrow rims finely striated on surface, or pectinate on free margin. Fifth legs are short rod-like processes present at caudo-lateral angles of the genital segment and are provided with three short plumose spines at their truncate end. Sixth leg rudiments are much smaller tubercles, situated just ventrally to the fifth and tipped by a single plumose spine.

Caudal rami parallel with each other, as long as broad, more or less quadrate, ending in three long terminal plumose spines and carrying, in addition, an inner and two outer, similar but much shorter spines. Inner border of the rami thickly ciliated.

Remarks: In the possession of well-expanded, semicircular genital segment and more or less elongate, indistinctly two-segmented abdomen, the new species is nearly allied to *bombayensis* Rangnekar, *oligoplitisi* Carvalho, *seriolae* Yamaguti, *hoplognathi* Yamaguti, *ligusticus* Brian, *torpedinis* Heller and *robustus* Bassett-Smith. It differs from *bombayensis*, *seriolae* and *hoplognathi*, for the first ground, by the possession of prominent triangular bulge on the second maxillipeds. It is distinguished, further, from the first of these species by the relatively shorter abdomen and by that the branches of the sternal fork are not expanded into broad lamellae, from the second, which it resembles in the

structure of the four pairs of legs, by the smaller genital segment and narrower abdomen, and from the third by having the fourth legs four-jointed. In the structure of the second maxillipeds and in that of the fourth legs, the new species is closest to *oligoplitisi* and *robustus*. It is different from the former of these in the broader, better round genital segment and in the shorter abdomen, and from the latter in the genital segment, lacking in a wrinkled neck, and in

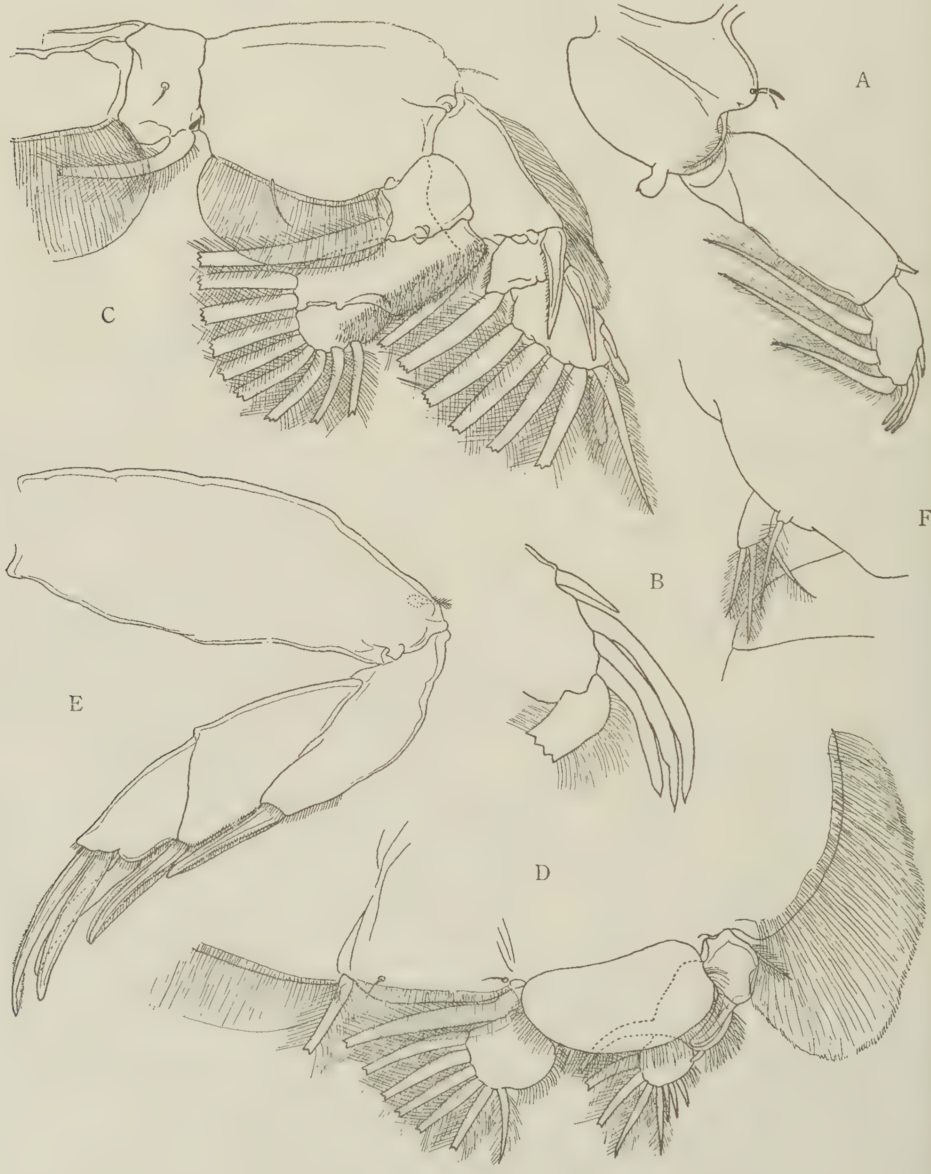

Fig. 6. *Caligus laticaudus* sp. nov., female. A, first leg; B, apical spines of same; C, second leg; D, third leg; E, fourth leg; F, postero-lateral angle of genital segment, ventral view. A, C–E ×120; B ×340; F ×170.

the broader abdomen. Although the new species closely resembles *ligusticus* in the size of genital segment and abdomen relative to the body, they are different from each other in the constitution of the terminal spines on the first legs, and in that the new species has an eminent process on the palm of the second maxillipeds. Differences from *torpedinis*, to which the new species is allied in the armature of the fourth legs, consist in the broader abdomen and the shorter fourth segment of the new species.

Genus *Lepeophtheirus* NORDMANN

Lepeophtheirus nordmanni (M. EDWARDS)

M. EDWARDS 1840, Hist. Nat. Crust., **3**: 445; SHIINO 1957: 359–364, figs. 1–2; 1959: 347–348. For other literature refer to SHIINO 1957.

Occurrence: On the body surface of *Mola mola* (L.) collected at Toba by T. KATAOKA, December 1958.

Specimens: No. 542, six females without egg strings. Body pale yellowish, nearly white, 13.5×6.1 mm in the largest specimen.

Lepeophtheirus muraenae sp. nov.

(Figs. 7 and 8)

Occurrence: On the body surface of *Muraena pardalis* T. et S. collected at Ooshima Island, off Wagu, on August 3, 1955, by myself.

Specimens: Six adult females with egg strings, one juvenile female and one adult male.

Female: Holotype. Color in alcohol pale yellowish, without pigmentation. Length 3.95, carapace 2.68×2.50, same inclusive of lateral flanges 2.86 wide, fourth thoracic segment 0.21×0.61, genital segment on the midline 0.86 long, including lateral lobes 1.04 long, 1.14 wide, abdomen 0.29×0.29, egg string 2.08 long (all in mm).

Carapace convex above, concave below, ovate, but only slightly narrower anteriorly than posteriorly; lateral margins widely round and bordered with rather broad membraneous flange. Frontal plates not prominent, about two thirds the entire width, widely round on free margin and with very narrow rim. Medio-posterior lobe widely round though more or less undulated, and protruding backward beyond lateral lobes which are narrow and blunt. Lateral sinuses small, shallow, triangular, opening wide. Longitudinal dorsal sutures slightly divergent both forward and backward, and separating narrower lateral areas of the carapace from far broader central area. Eyes placed in the middle of the anterior half of the central area.

Fourth thoracic segment short and narrow, a quarter as wide as carapace,

one third as long as its own width, transversely linear and blunt on either side. Genital segment relatively small in size, about one third as wide as carapace and shorter than wide. It has gracefully curved shoulders, parallel sides and incurvated posterior margin, forming on either side a pair of short blunt lobes.

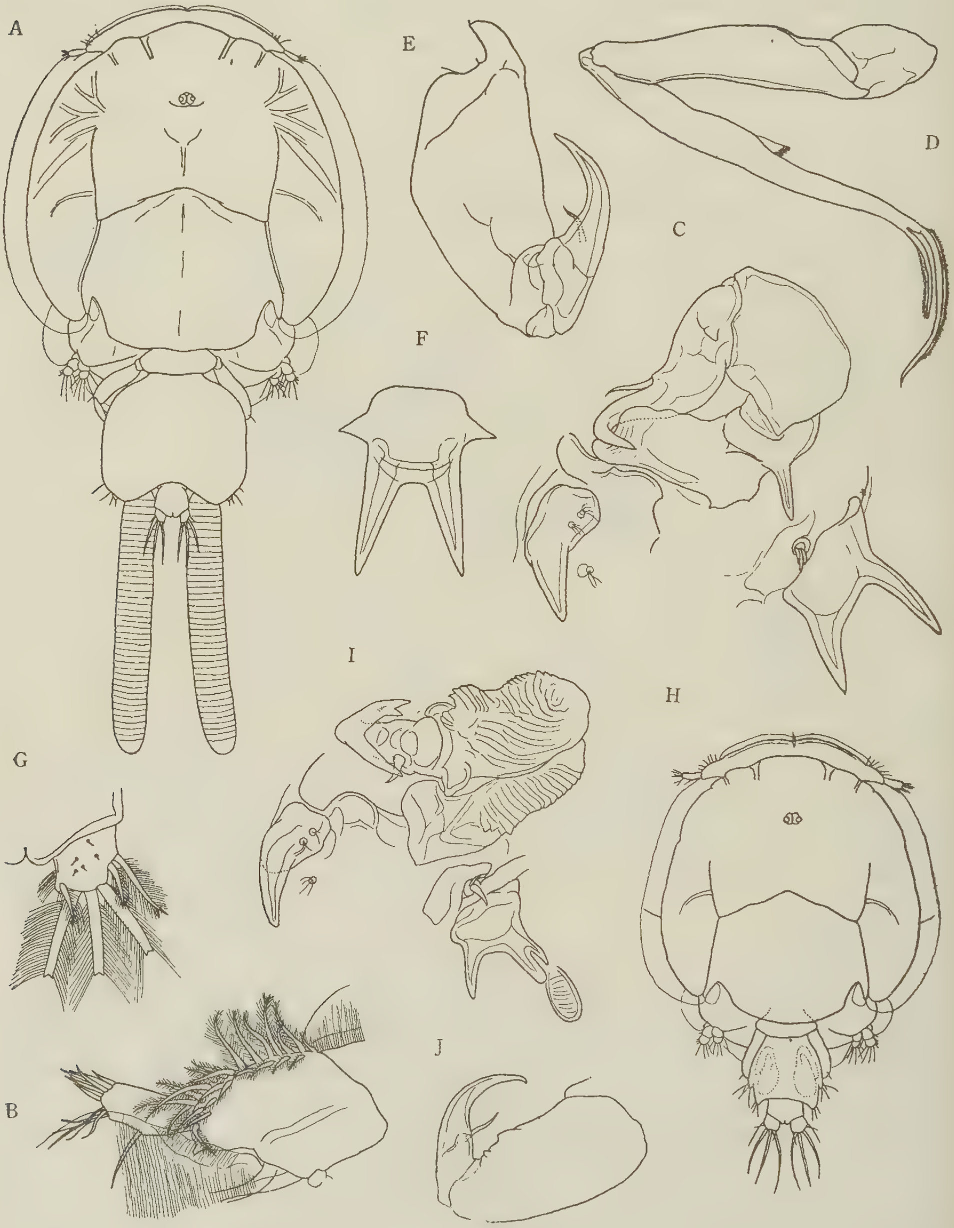

Fig. 7. *Caligus muraenae* sp. nov. A–G, female; A, dorsal view; B, first antenna; C, second antenna and two maxillae; D, first maxilliped; E, second maxilliped; F, sternal fork; G, caudal ramus; H–J, male; H, dorsal view; I, second antenna and two maxillae; J, second maxilliped. A ×16.8; B ×95; C–G ×85; H ×24; I, J ×110.

Abdomen very small in size, a quarter as wide as the preceding segment, as long as its own width, somewhat narrowed forward, and obliquely truncate on either lateral angle of caudal margin.

First antennae short; apical joint thick and short, bearing a long solitary spinule on posterior side besides numbers of apical hairs; basal joint irregularly rhomboid in shape and fringed with double row of plumose spines. Second antennae with joints bent in deltoid shape; basal joints transversely prolonged and reinforced on posterior side near the distal end with an elongate styliform process, second joint the shortest of all, but broadest and columnar, and third joint curved twice on different planes, forming a sharp, hook-like apex and furnished at the base with a short, broadly unguiform spine and about the middle with a longer, thinner hair. First maxille have a quadrate base provided with two tubercles bearing fine spinules and an acuminate apex, which, making an obtuse angle with the base, does not show any curvature. Sternal surface just inside the maxillary apex carries another tubercle with fine spinules. Second maxillae are bifurcate and composed of short broad base and two sharp claws of subequal length, which are widely apart from each other and a little divergent; inner claw is narrower than the outer; endopodite consists of three short spinules arising from a tubercle. Terminal joint of first maxillipeds is slenderer and a little longer than the basal, terminates in two unequal flagella with pectinate rims and bears at the centre of its length a triangular lamina, finely fringed on distal margin. Second maxillipeds are powerful and composed of greatly swollen palm and robust, strongly curved claw, which hardly reaches the base of palm with the sharply pointed tip and carries a short hair about the middle. Two branches of sternal fork are directed straight backward, only slightly divergent and attenuated to a sharp point, interposing between each other a V-shaped sinus; the base is quadrate, wider than long and armed on either side with a short, sharply pointed, laterally projected process.

Endopodite of first legs a very thin, spiniform process of protopodite. Two rami of third legs short and closely adjoining each other; endopodite shorter than the other ramus, two-jointed, and basal joint expanded outward into a lunular lamella; exopodite three-jointed, though the basal joint almost rudimentary. Fourth legs four-jointed; first joint about as long as last three combined together; these latter relatively slender and bounded one from another by oblique border as usual. Details of the armature on the first four pairs of swimming legs are as represented in Table III.

Non-plumose spines on the first legs are pectinate on the inner border and inner two of them are bifid in addition. External spine on the first two exopodite joints of the second legs and basal spine on the third joint have pectinate rims on two opposite borders; second spine on the latter joint with

Table III. Details of the armature on the legs of *Lepeophtheirus muraenae* sp. nov.

Leg	Border	Sternal plate	Protopodite		Exopodite			Endopodite		
			I	II	I	II	III	I	II	III
I	outer inner		1p 1p		1rh c	3H, 1p 3P				
II	outer inner	f	1s 1P	f, 1p f, 1s	f, 1H c, 1P	1H c, 1P	2H, 1Q c, 5P	c 1P	c c, 2P	c c, 6P
III	outer inner	f	f, 1p 1P, f, 2s		1H' 1P	c, 1h c, 1P	c, 3h c, 4P	c 1P	c c, 6P	
IV	outer inner		1p		2s, 1rh	1H	3H			

broad marginal membranes instead of pectination and the third spine with again broader outer membrane. Basal hook on the exopodite of the third legs is obtusely bent and has the apex straight and simply tapering to a point. Apical spines of the fourth legs are graded in length from the inside to the outside, the innermost being about thrice as long as the outermost, to which the spine on the third joint is subequal. All of them are doubly edged with narrow pectinate rims except for the innermost of the fourth joint, which has merely an outer rim. They are, together with the rudimentary spine on the second joint, accompanied at the base with a crescentic, striated lamina. Fifth legs are a pair of single short plumose spine surmounting on a papilla which is present on the ventral side of the genital segment close to the caudo-lateral angle. Sixth legs are triangular laminae located internally to the fifth and hardly visible in dorsal view. They carry three plumose spines along the external border and a number of short hairs on the surface. Caudal rami are tiny in size, short, broader than wide. Besides three long plumose, terminal spines, they bear two shorter similar spines on the outside of these, a single similar one on the inside, a number of tiny hairs on the surface and a row of hairs on the inner border. Egg tubes packed with uniserial eggs.

Male: Allotype. Coloration as in female. Length 2.11, carapace 1.51 × 1.43, same including lateral flanges 1.45 wide, fourth thoracic segment 0.15 × 0.35, genital segment, on the midline 0.33 long, same in lateral regions 0.40 long, 0.40 wide, abdomen 0.15 × 0.20 (all in mm).

Carapace closely resembling that of female in outline as well as in proportion of parts, frontal plate slightly depressed on the median and medio-posterior lobe better round. Fourth thoracic segment narrowed forward and partly concealed under the carapace. Genital segment about a quarter as long as the carapace, as long as its own width and narrower anteriorly than posteriorly; sides gracefully curved, bearing a short, posteriorly directing spiniferous process in front of the hinder end and forming a triangular, similarly

Fig. 8. *Caligus muraenae* sp. nov. A–H, female; A, first leg; B, apical spines of same; C, second leg; D, third leg; E, fourth leg; F, spine of third joint of same; G, spine of second joint of same; H, posterior end of genital segment, ventral view; I, male, lateral border of genital segment, ventral view. A, C–E, H ×85; B, F, G ×150; I ×110.

spiniferous lobe at the extreme end. They represent fifth and sixth leg rudiments. Abdomen relatively a little wider than in female, wider than long, and with caudal margin obliquely truncate on either side.

Second antennae have the second joint bent over the first and in line with the third. First joint corrugated on surface by a series of parallel streaks. Second joint also corrugated, provided with two terminal protuberances, one on each side, and with another corrugated boss just behind them. Third joint recurved and deeply forked at the tip into two sharp divergent branches; anterior member of these with a short secondary branch on inner side; the

joint armed, further, with two hairs near the base, one on anterior side and the other, which is stronger, on posterior side. First maxillae more or less resembling those of female in structure. Second maxillae tripartite at their apices; outer and inner branches alike, styliform, pointed at the tip, though the inner much shorter, middle branch blunt, lying far closer to the latter than to the former. Just behind the second maxilla on either side of the midline, sternum is raised into an obovate, corrugated ridge. Second maxillipeds as stout as those of female and similar in structure except for having a few inconspicuous bulges on inner border of palm. Fifth legs with four short plumose spines and the sixth with three of these. Terminal spines on caudal rami relatively better developed than in female.

Remarks: In the configuration of the genital segment, which is wider than long, in its size proportional to the carapace (1 : 3 in length), in the bifid second maxillae and in the four-jointed fourth legs, the second joint of which carries a rudimentary spine instead of a fully-developed one, the female of the new species is nearly allied to the same sex of *rotundiventris* BASSETT-SMITH, *sekii* YAMAGUTI, *goniistii* YAMAGUTI, *elegans* GUSSEV, *scutiger* SHIINO and *plectropomi* NUNES-RUIVO et FOURMANOIR. It is distinguished from all of these by the first maxillae not being curved like a hook, by the branches of the second maxillae being widely separated and divergent and by the sternal furca having parallel, sharply pointed branches. The genital segment in the new species is different from the corresponding segment of the first of those species in its emarginate posterior margin, from that of the third in the absence of a pair of triangular lobes on the same margin and from that of the last three in being distinct from the fourth thoracic segment. The basal hook on the exopodite of the third legs is simple unlike the same of *goniistii*. The fifth legs are neither produced so far backward as in this species, nor styliform as in *plectropomi*.

The male is closely resembling in its general appearance to the corresponding sex of those species except *rotundiventris*, where the genital segment is bilobed posteriorly. The tripartite apex of the second antennae, however, constitutes the most distinguishing character of the new species.

Genus *Trebius* KRØYER

Trebius akajeii SHIINO

SHIINO 1954, Rep. Fac. Fish., Pref. Univ. Mie, **1**: 252-258, Figs. 3-4.

Occurrence: No. 531; on the external surface of *Dasyatis akajeii* (MÜLLER et HENLE), July 20, 1959. No. 533; on the external surface of *Rhinobatos schlegelii* (MÜLLER et HENLE), July 22, 1959. Both the lots were collected at Hamazima by myself.

Specimens: No. 531; two females and a male. One of the females measuring 4.2×1.4, with egg strings 1.4 long, the other 3.4×1.5 and corresponding to the female shown in Fig. 3D inserted in one of my previous works (1954a). Male 2.2×1.0. No. 533; three females. The largest of them 4.7×1.6, the second 4.4×1.7, with egg strings 1.8 long, the third 2.8×1.2, and corresponding to the female shown in Fig. 3D of my previous work (1954a). (Measurements are given in mm in all cases.)

Genus *Pandarus* LEACH

Pandarus satyrus DANA

DANA 1852, U. S. Explor. Exped. 8: 1367, Pl. 45, Fig. 1; SHIINO 1954b. 312–325, Figs. 11–17; 1957: 364; 1959a: 352–353. For further literature and synonymy refer to SHIINO 1954.

Occurrence: On the external surface of a shark collected at Daiôzaki Point, July 30, 1959 (No. 540).

Specimens: 16 females with black color markings and carrying egg strings, the largest of them 7.4×4.8, with egg strings 10.4 long. Seven females colored in brown and with egg strings and seven pale brownish or non-colored females without egg string. One younger female corresponding to the one illustrated in Fig. 15 inserted in one of my previous works (1954), 7.5×4.2. Nine adult males, the largest of them 7.5×4.2, and seven younger males corresponding to the stage in Fig. 16 of that work, 5.4×2.6. (All the measurements are given in mm.)

Genus *Gangliopus* GERSTAECKER

Gangliopus japonicus sp. nov.

(Figs. 9 and 10)

Occurrence: One female specimen with egg strings obtained from the body surface of *Sphyrna zygaena* L. at Hamazima, by myself, July 20, 1955.

Female: Holotype. Body depressed, semitransparent, covered by rather thin soft skin, surface of which bears spines in none of the regions of body. Color pale yellowish grey in alcohol, somewhat darker in the central region of carapace, while paler and more or less tinged with green in the marginal region; no black pigment spot. Egg strings yellowish. Total length 6.30, carapace, on the midline 2.29 long, same in lateral region 3.18 long, 3.62 wide, second thoracic segment, central region 0.52×1.48, same, including dorsal plates 1.38×2.71, third segment, central region 0.29 long, same, including dorsal plates 1.14×2.48, fourth segment, on the midline 0.38 long, same, including dorsal plates 1.19×2.14, genital segment, on the midline 1.76 long, same in

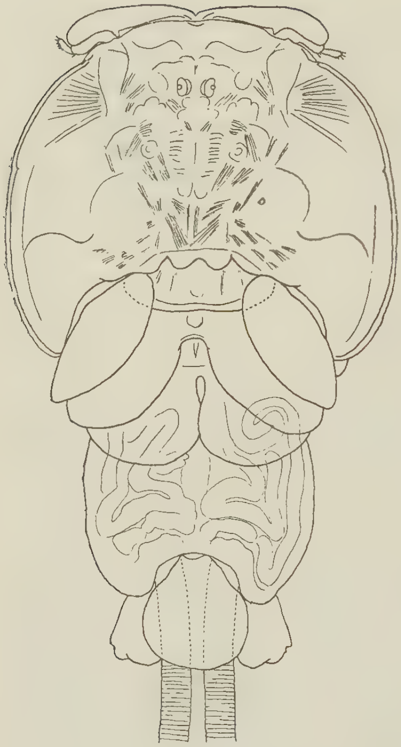

Fig. 9. *Gangliopus japonicus* sp. nov., dorsal view of female. ×14.

lateral region 2.19 long, 2.19 wide, sixth segment 1.10×1.00, abdomen 1.20×1.15, its free region posterior to caudal rami 0.38×0.80, egg string 11.9 long (all in mm).

Carapace circular in outline, but deeply excavated posteriorly in a crescentric form. Frontal plate two-thirds the entire width, narrower medially, broader laterally, with margin only slightly arched on either side of the shallow median notch and ending laterally in blunt linguiform lobes, which are separated from the carapace by a narrow fissure for some distance from the apex. Sides of carapace widely round, with a very inconspicuous notch in front of the middle and bordered with a very narrow transparent flange. Posterior margin uneven in the central region, but evenly incurvated in lateral regions; a pair of round submedian bulges of the margin, which insert between each other a round median sinus, continue laterally past an acute incision to a slight undulation and then to the evenly curved region. Lateral lobes triangular, blunt at the end. The carapace furnished on the ventral surface with three pairs of adhesive pads irregularly oval in shape and graded in size; first pair, the largest, lying close behind the basal joints of first antennae, second, of medium size, just behind and outside the bases of second antennae, and third, the smallest, inside the attachments of first maxillipeds and in front of the basal musculatures of second maxillipeds. All the pads very finely corrugated on their surface. Eyes at a short distance behind the anterior border of carapace.

First thoracic segment narrow, coalesced with the carapace, under whose lateral lobes the first legs are entirely concealed. Succeeding three segments provided each with a pair of well-developed dorsal plates; the consecutive plates overlapping from before backward. Second segment short and narrow in central region, two fifths as wide as carapace and with dorsal plates widely apart from each other. Those plates divisible on either side into an anterior portion covered from above by the carapace and a posterior portion exposed on dorsal side; the former portion straight on fore margin, curved on the side and with an oblong oval pad at antero-lateral angle; the latter portion spindle-shaped,

directed diagonally backward and covering small lateral portion of the segment proper. The segment bears another oval pad on the sternum on the midline just in front of second legs. Dorsal plates of third segment oblong ovate in outline, standing side by side, but separated from each other by a deep, chevron-like, median sinus. The corresponding plates of fourth segment well round and placed so close to each other as to overlap slightly, though entirely separated by a deep median incision. Genital segment about three fifths as wide as carapace, as long as its own width, two sides widely curved, hinder border excavated in the form of a crescent, and caudo-lateral angles produced into blunt lobes. Sixth segment flattened, circular in outline, lying dorsally to abdomen and inserting its short, rapidly tapering neck into the posterior excavation of the preceding segment. Abdomen also flattened, attached to the caudal end of the genital segment on the ventral level. Posteriorly, it is insensibly divided into two round lobes, without exceeding the sixth segment, and anteriorly it has strongly uneven sides which are bulged into a number of large and small projections. Caudal rami arise from the sides of abdomen and, lying dorsally to this, extend diagonally so far back as the end of the sixth segment. Genital segment trails the egg strings which are inserted between the sixth segment and the abdomen; they are packed with uniserial, disc-like eggs.

First antennae two-jointed; apical joint extraordinarily short and tipped by several short spinules; basal joint far longer, plentifully supplied at the end with short spines coated with very fine hairs and with a few simple spinules in addition. Second antennae feeble, three-jointed; basal two joints short and simple, without armature, whereas apical joint elongated, abruptly narrowing near the apex to form a hook, and with two tiny hairs, one near the base and the other near the apex. Mouth tube slender, elongated conical. First maxillae absent. Second maxillae just outside the base of the mouth tube and composed of broader base and narrower, internally directing apical joint which is tipped by a single unguiform spine. First maxillipeds short, two-jointed; terminal joint shorter than the basal, ending in two unequal claws, ornamented with longitudinal lines of fine pectination, and carrying close to the base of the shorter member a very short, apically truncate, additional claw. Second maxillipeds robust, two-jointed and richly supplied with strong basal musculature; terminal joint swollen, lacking movable finger, but with distal and proximal bosses on the surface; the former of these larger, uneven owing to the presence of tubercles and flattened plates of irregular shape.

Four pairs of legs biramous, flattened and membraneous. Both the rami two-jointed in first three pairs, while one-jointed in the last pair. First pair is strongly reduced in size and the members of both sides are combined together

Fig. 10. *Gangliopus japonicus* sp. nov., female. A, anterior region of carapace, ventral view showing two antennae, mouth tube, maxillae and adhesive pads, B, first maxilliped; C, second maxilliped; D, first two thoracic segments, ventral view showing first and second legs; E, third and fourth legs; F, exopodite of third leg; G, endopodite of fourth leg; H, posterior end of genital segment with abdomen and caudal rami, ventral view; I, apical margin of caudal ramus. A–D, F, G ×47; E ×37; H ×24; I ×75.

by a narrow median chitinous bar. Protopodite is more or less trapezoid in form and furnished with a small triangular corrugated pad. Endopodite is shorter than exopodite and has another corrugated pad on the first joint. Second legs are much larger than the first in size. Protopodite is enlarged into an oblong plate, produced externally at the anterior angle into a short blunt process and connected on the inside with a large semicircular sternal plate, just outside of which it bears a large-sized adhesive pad. Endopodite consists of short basal and much longer, oval apical joints. Exopodite is shorter than endopodite and composed of subequal joints. Protopodite of third legs is strongly dilated into a roughly quadrilateral plate, which is, nevertheless, widely round on outer and inner borders; it carries at the antero-internal angle an irregularly oval pad and is coalesced on inner border for a short distance with an antero-posteriorly elongate, quadrilateral sternal plate, which it slightly covers. Exopodite is half as long as endopodite; basal joints of both of them are subequal in size, but their apical joints are widely different, being inflated in the latter into an oval lobe, while much reduced in length and width in the former. Last pair of legs have the protopodite dilated as in the preceding pair, but they are entirely separated from each other without the intervention of a sternal plate. Their rami are oval in form and subequal in size. Number of spines, their sites on the rami and the same of the spinulated areas on the four pairs of legs are shown in Table IV.

Table IV. Details of the armature on the legs of *Gangliopus japonicus* sp. nov.

Leg	Border	Sternal plate	Protopodite	Exopodite		Endopodite	
				I	II	I	II
I	outer inner		1h 1h, B	1H	3h, CC 3H	B	CC 3H
II	outer inner	CC	CC, 1h, CC B, CC	CC, 1H	CC, 3H, 1H 6H	CC	CC, 2h 5H
III	outer inner	CC	CC, 1h, CC B, CC	CC, 1h	CC, 4h, 1H 3h	CC	CC 4h
IV	outer inner		CC, 1h CC	CC, 3h, 1H 2h		CC	

Spines on the legs are for the greater part without any pectination. Apical spine on the second exopodite joint of the first legs broad, conical and thickly covered with hairs. The same on the exopodite of the next pair of legs also conical, but without hairs, the same on the third blunt and recurved, and the same of the fourth simply blunt. Fifth and sixth thoracic segments limbless. Caudal rami broad, quadrate in form and with a slight bulge on hinder border near lateral corner; they bear a longer slender and a shorter conical

spines at lateral end of this margin, two conical ones on the bulge and three tiny spinules further internally.

Remarks: The genus *Gangliopus* Gerstaecker (1854) was precisely defined by the original author on the basis of the type species *pyriformis* Gerstaecker. Wilson (1907) gave another diagnosis and pointed out some mistakes in the original description, without his actual observation of the specimens. He emphasized further that *Nogagus angustatus* Gerstaecker, which lived on the same host together with *Gangliopus pyriformis* and was described on the same occasion, may represent the male of the latter. Monod and Dollfus (1938) were the second authors who could examine the female of *pyriformis*. Based on their own observation, they gave a more precise and more rational diagnosis, inserting excellent figures on the entire view of the animal and on its appendages. So far as I am aware, since then, no second species belonging to the genus has been discovered.

Although the female described above agrees well with the generic diagnosis given by those authors, it differs from the type species in certain details. The carapace of the new species is circular in outline, setting aside the posterior emargination, and is different from an obovate form of *pyriformis*. The first dorsal plates (belonging to the second thoracic segment) are distinctly demarked from the central region of the segment, which they partly overlap. The second plates are apart from each other somewhat more widely than in the type species, in which they are almost in contact on the midline. The third plates, which are separated by a triangular incision in that species, are so close to each other in this species that they partly overlap. The sixth segment is of relatively far larger size than in that species. The abdomen is not simply round on caudal margin, but is more or less quadrate in shape and slightly bilobed.

In addition to these, there are another lot of differences in connection with the structure of the thoracic legs, not to mention of the armature with which they are armed. The terminal exopodite joints of the second to fourth legs are not so elongate as in *pyriformis*. They are relatively shorter and much broader. The sternal plate belonging to the second legs is lunular in shape instead of triangular and has a widely round free border. Two rami of the fourth legs are shorter and ovate. Finally, in contrast to the lengths of 9–10 mm in *pyriformis*, the body of *japonicus* is much shorter, measuring only 6.3 mm.

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Copepods Parasitic on Fishes from Seto, Province Kii, Japan

(*With seven Text-figures*)

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From time to time, the copepod species parasitic on the fishes have been recorded from Seto, Province of Kii. They amount at present to a considerable number. The collection I have examined recently comprises the males of the two species, *Bomolochus leptoscari* YAMAGUTI and *Taeniacanthus longichela* YAMAGUTI et YAMASU, both of these having been known only from the females. Although they have been fully described by the original authors, I feel it necessary to give here a supplementary account, especially with respect to their sexual dimorphisms. The third of the species here dealt with represents a new form, *Lepeophtheirus hastatus* sp. nov. which is erected upon the female specimens.

Genus *Bomolochus* NORDMANN

Bomolochus leptoscari YAMAGUTI

(Figs. 1–3)

YAMAGUTI 1953, Publ. Seto Mar. Biol. Lab., **3**: 222–223, Pl. 1, Figs. 9–11, Pl. 2, Figs. 12–18.

Occurrence: Numerous females and males were found on the outside surface of *Leptoscarus japonicus* (C. et V.) at Seto by myself, April 21, 1954. Both sexes were crawling over the outside or inside of the scales.

This species was erected by YAMAGUTI on the basis of the female specimens, and so far as I am aware, no male has been recorded. The present collection contains a number of male forms which are much different from the female in their structure. As some of them were found seizing the female in the act of copulation, there lies no doubt in that they are conspecific with this.

Female: Body depressed dorso-ventrally and somewhat more strongly compressed antero-posteriorly than in the holotype, 0.90 in total length, carapace 0.43×0.55, second thoracic segment 0.13×0.57, third segment 0.09×0.55, fourth segment 0.08×0.27, fifth segment 0.02×0.18, genital segment 0.07×0.16, first abdominal segment 0.02×0.09, second segment 0.02×0.07, third segment 0.04×0.06, caudal ramus 0.04 long. Transparent and colorless, without any pigment. Egg case 0.44×0.21, flattened, containing a single layer of whitish eggs. (All measurements in mm)

Fig. 1. *Bomolochus leptoscari* YAMAGUTI, female. A, dorsal view; B, first antenna, dorsal view; C, same, ventral view; D, second antenna; E, mouth parts, from mandible to first maxilliped; F, second maxilliped. A ×75, B ×160, C, F ×305, D, E ×440.

Carapace and first two thoracic segments contiguous on the sides and succeeding segments much more shortened than in the holotype. Abdomen exceedingly small, occupying only one tenth of the entire length. Second maxillipeds lie laterally to other oral appendages, and carry three short plumose setae on basal joint around the junction with apical joint, and another similar, but shorter one near each outer end of sternal bar which combines the members of both sides. Armatures on five pairs of thoracic legs are as indicated in the following diagram (Table I).

Table I. Details of the armature on the legs of the female of *Bomolochus leptoscari* YAMAGUTI*

Leg	Border	Sternal plate	Protopodite	Exopodite			Endopodite		
				I	II	III	I	II	III
I	outer inner	 CC	1P 	1h 1h	1s, 2h 6P		c 1P	c, 3P 3P	
II	outer inner	 T	1h 	1h 	1h 	3h 2H	c 1H	c 	 3H
III	outer inner	 T	1h 	1h 	1h 	3h 2H	c 1h	c 	 2H
IV	outer inner	 T	1p 	c, 1h 	1h 	c, 2h, c 1H	c 1h	c 	 2H
V	outer inner		1p 	CC 1H, 1h					

Two rami of first legs two-jointed and bearing flattened spines, thickly fringed with short hairs. Protopodite produced inward into a narrow acuminating lamella, edges of which are thickly hairy; this probably represents a modified spine. Sternal bar has a pair of lateral areas which are thickly covered by several transverse rows of short fine spinules. Corresponding bar of succeeding legs bears rows of tubercles instead of spinules. Except the solitary spine on protopodite, all other spines on these legs non-plumose. Fourth legs have at the base of protopodite a triangular process, which is blunt in the third legs and rudimentary in the second. Fifth legs bear on their ventral surface a narrow external subterminal area which is thickly covered with fine spinules. Sixth segment carries two simple spinules in the immediate neighborhood of each

* Abbreviations used in Tables I∼V:—

c, row of hairs; CC, area covered with spinules; f, membraneous flange; H, longer simple spine; h, shorter simple spine; H′, hook-like spine; L, lamellar expansion of joint; P, longer spine doubly edged with hairs; p, shorter spine with double row of hairs; P′, longer spine with multiserial hairs; p′, shorter spine with multiserial hairs; pc, pectination; Q, spine hairy on one side, with membrane on the other side; rh, rudimentary spinule; s, solitary hair; T, tuberculation. Roman numerals indicate the numerical orders of legs, or of joints, and arabian numerals indicate the number of spines, or other armatures present on them.

oviducal pore. Caudal rami end in a single, much elongate spine, which is associated at the base on the inside with an incomparably short spinule, on the

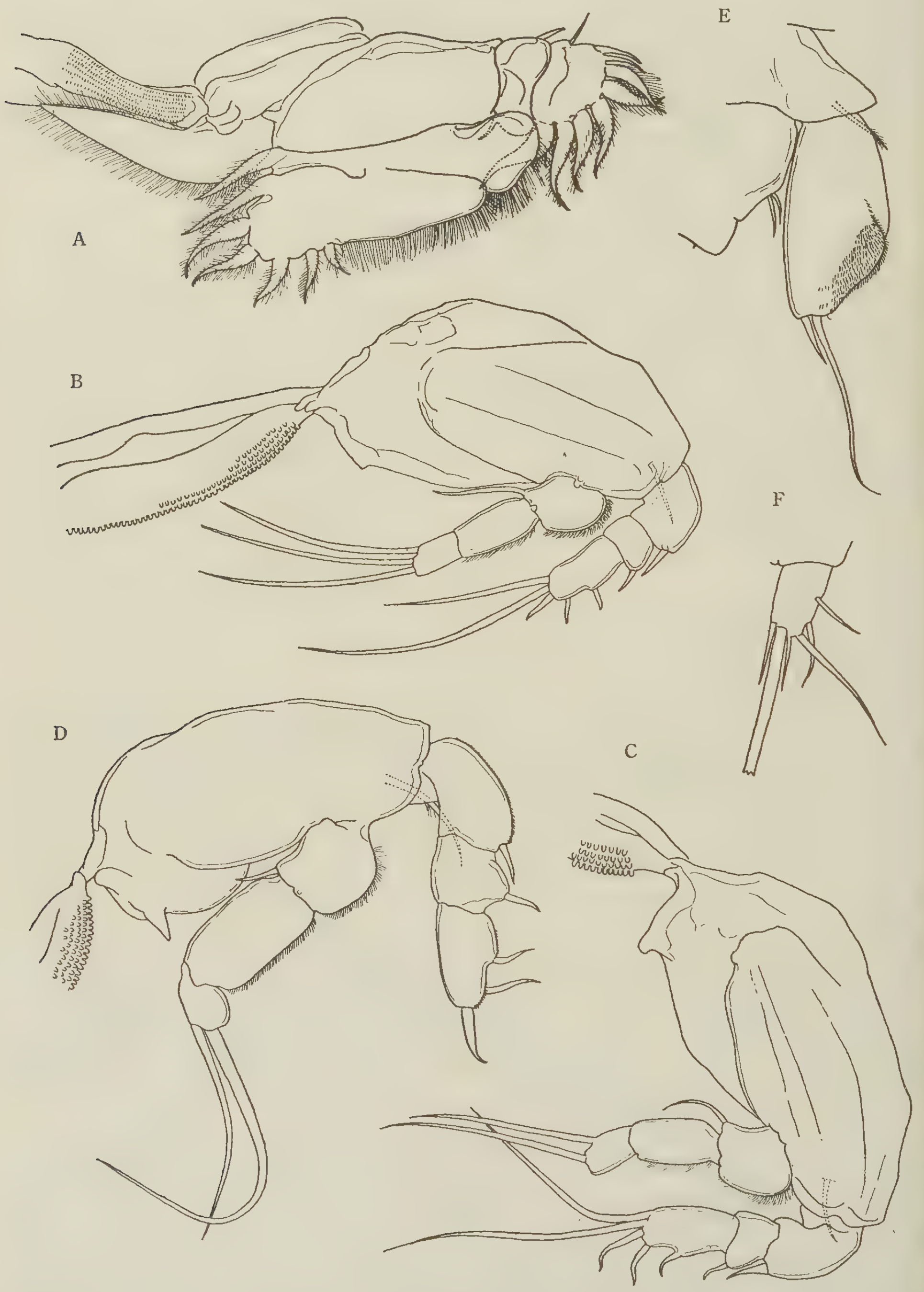

Fig. 2. *Bomolochus leptoscari* YAMAGUTI, female. A, first leg; B, second leg; C, third leg; D, fourth leg; E, fifth leg; F, caudal ramus. ×305.

outside with similar three and about the middle of the outer border with another; all the spines non-plumose.

Male: Allotype. Far smaller than female in body size and much different in the structure of body and of appendages. Total length 0.46, carapace 0.22×0.21, second thoracic segment 0.04×0.17, third segment 0.03×0.15, fourth segment 0.03×0.10, fifth segment 0.02×0.08, genital segment 0.06×0.08, first abdominal segment 0.03×0.05, second segment 0.02×0.05, caudal ramus 0.03 long (all in mm).

Carapace a little longer than wide, ovate in outline though truncate on hinder border. Fore margin slightly notched on either side and with frontal lamina wider, but less prominent than in female. Succeeding three segments contiguous on the sides, subequal in length, but successively and rapidly narrowing backward so as to form together with the carapace an obovate outline of anterior body region. Their combined length exactly half that of carapace; fourth segment a half as wide as the second which is slightly narrower than carapace. Consecutive segments bordered by forwardly arched boundaries, though the fourth straight on hind border. Unlike those, the fifth wider posteriorly than anteriorly and represented by a short transverse, linear segment. Genital segment is nearly as wide as the fifth, from which it is bordered by a straight line; it is only shorter than wide and has parallel sides which curve in toward each other near posterior end. Abdomen is somewhat shorter than the preceding segment, about as long as wide and composed of two subequal segments; the posterior segment truncate at caudal end.

First antennae relatively longer than in female and somewhat different in the armature of their joints. They are six-jointed, having the second and third joints more or less coalesced together. Marginal plumose spines on the first two joints slenderer, but stiffer than those of female, setiform; second joint carrying three of them on the ventral surface, the third with a simple and a plumose spines and the terminal three with spines much longer than in female. Second antennae and oral appendages as in this sex. Second maxillipeds subcheliform. Basal joint dilated into a triangle, tuberculated along straight inner border in several rows and thickly hairy on proximal half of well-arched outer border. Apical joint a sickle-form, only slightly curved and folded back over the basal joint, to whose proximal end its narrowed tip extends. It is tuberculated on inner border and furnished with a stiff hair near the base.

Unlike the corresponding pair of female, the first pair of thoracic legs resemble the succeeding pairs in their structure; both the rami are three-jointed; the endopodite has the boundaries of joints obliterated. Second and third pairs carry distinctly three-jointed rami and are resembling each other in structure except for that the third pair lack the external spine on the second exopodite

joint. Fourth pair have exopodite three-jointed, while endopodite two-jointed. Fifth pair are much narrower than in female and yet composed of two joints.

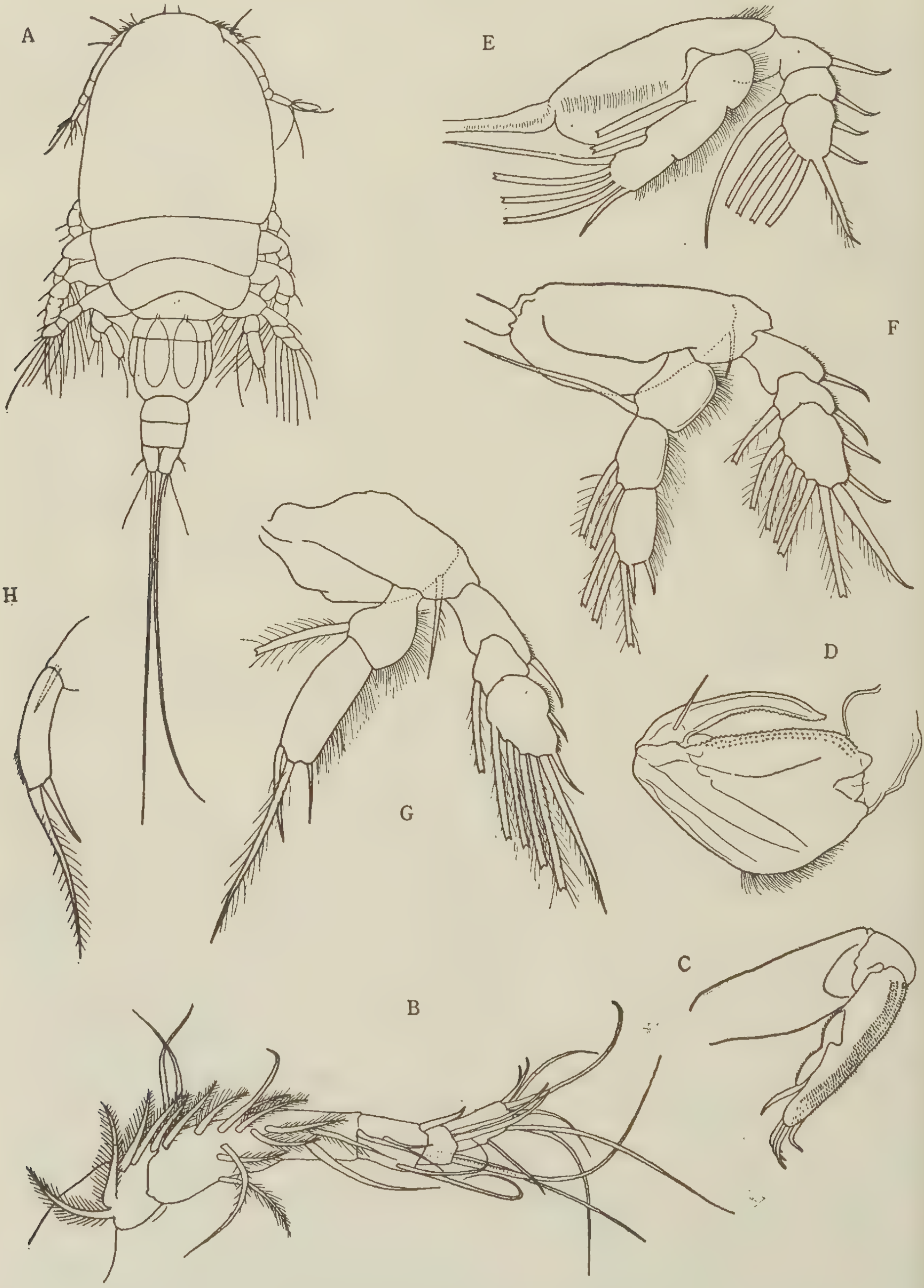

Fig. 3. *Bomolochus leptoscari* YAMAGUTI, male. A, male; B, first antenna, ventral view; C, second antenna; D, second maxilliped; E, first leg; F, second leg; G, third leg; H, fifth leg. A ×125; B, D, F–H ×440; D ×155.

Spines and setae present on those pairs of legs are diagrammatically illustrated in Table II.

Table II. Details of the armature on the legs of the male of *Bomolochus leptoscari* YAMAGUTI

Leg	Border	Sternal plate	Protopodite	Exopodite I	Exopodite II	Exopodite III	Endopodite I	Endopodite II	Endopodite III
I	outer inner	 c	c c	c, 1h	c, 1h 1H	c, 2h 4H, 1P	c 1H	c 1H	c 1H, 4H
II	outer inner		1h	c, 1h	c, 1h 1P	c, 1h, c, 1h 6P	c 1H	c 2P	c, 2h 3P
III	outer inner		1h	c, 1h	c 1P	c, 1h, c, 1h 6P	c 1H	c 2P	c, 2h 3P
IV	outer inner		1p	c, 1h	 1P	c, 2h, c 5P	c 1P	c 1H, 1P, 1h	
V	outer inner		1h	c 1P, 1H					

Execpt in first pair, greater part of setiferous spines on the succeeding three pairs of legs are doubly edged with very sparse hairs. Sternal bar has neither hairy row, nor tuberculation in these pairs. Longer member of terminal spines on fifth legs is ciliated and subterminal spinulated area of female is replaced by a row of short hairs. Terminal spine on caudal rami exceedingly elongate, surpassing four fifths the length of entire body.

Remarks: The present species is charaterized, above all things, by the complete absence of hairy rows on the spines of the second to fourth pairs of legs in the female, though otherwise is the case with the male. The species is also noteworthy for its conspicuous sexual dimorphisms which are manifested not only in the general body structure but also in the details of thoracic appendages.

Genus *Taeniacanthus* SUMPF

Taeniacanthus longichela YAMAGUTI et YAMASU

(Figs. 4 and 5)

YAMAGUTI et YAMASU 1959, Biol. J. Okayama Univ., **5**: 99–100, Pl. 3, Figs. 44–55.

Occurrence: Four females and two males were found on the bottom of the gill cavity of *Cantherinus modestus* (GÜNTHER) by myself at Seto.

As the previous one, this species has been known from the female alone.

Female: Body convex dorsally, flattened ventrally. Color pale yellowish brown in preservative owing to ovaries full of ova; egg cases packed with pale

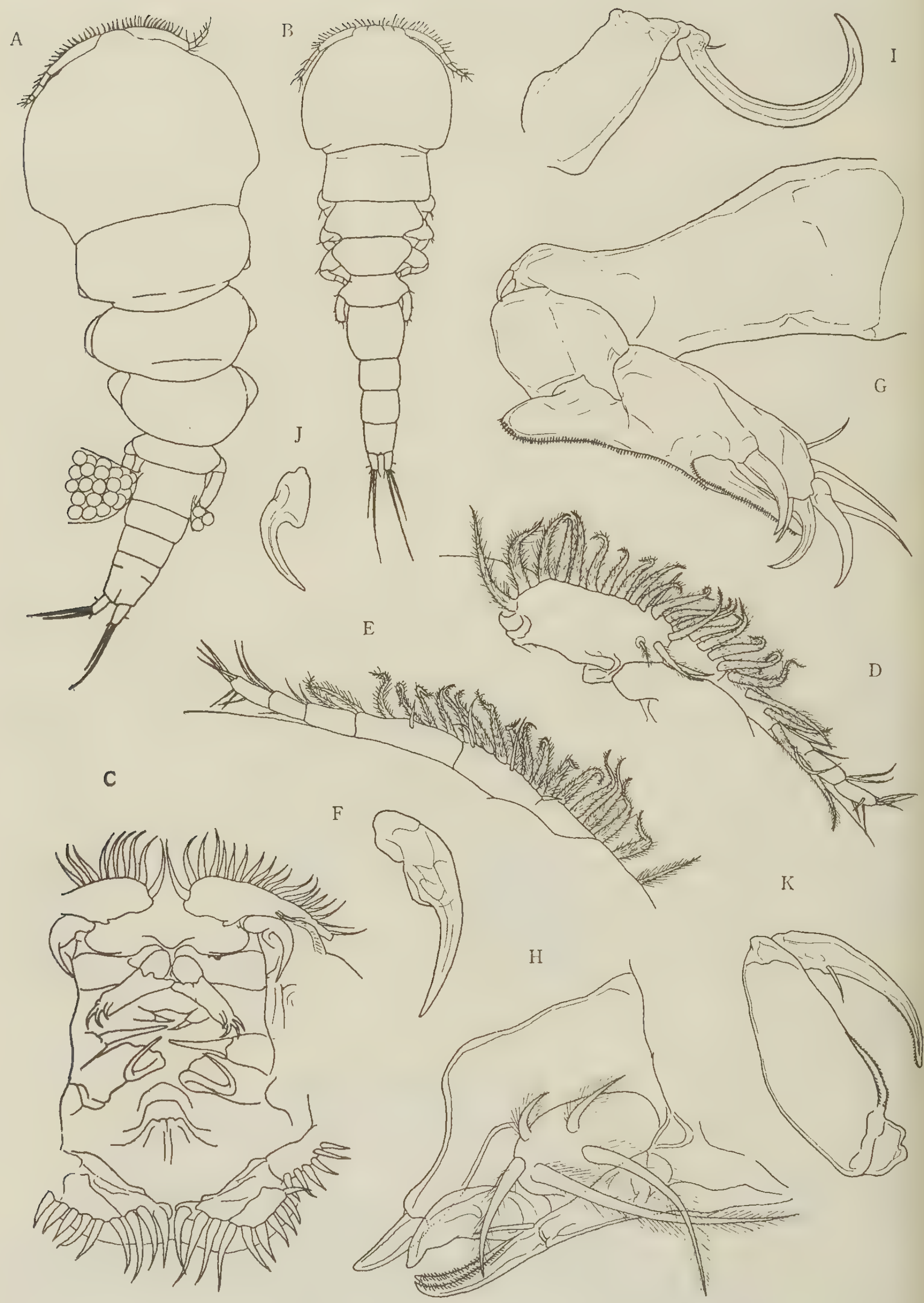

Fig. 4. *Taeniacanthus longichela* YAMAGUTI et YAMASU. A, female, dorsal view; B, male, dorsal view; C–I, female; C, head, ventral view; D, first antenna, ventral view; E, same, dorsal view; F, first maxilla; G, second antenna; H, mandible, second maxilla and first maxilliped; I, second maxilliped; J–K, male; J, first maxilla; K, second maxilliped. A ×37, B ×45, C ×75, D–F, I ×155, G ×335, H ×305, J, K ×185.

yellow eggs. Total length 2.26, carapace 0.72×0.90, second thoracic segment 0.36×0.67, third segment 0.28×0.61, fourth segment 0.25×0.47, fifth segment 0.07×0.34, genital segment 0.15×0.25, first abdominal segment 0.11×0.23, second segment 0.10×0.19, third segment 0.08×0.18, fourth segment 0.14×0.18, egg tube 2.69×0.29 (all in mm).

Carapace better swollen than in holotype, better round in front, reentrant at postero-lateral angles and forming a hollow on mid-ventral region. Except first antennae which are six-jointed, all the appendages are coincident in every detail with those of holotype. Armatures on five pairs of thoracic legs are as indicated in Table III.

Table III. Details of the armature on the legs of the female of *Taeniacanthus longichela* YAMAGUTI et YAMASU

Leg	Border	Sternal plate	Protopodite	Exopodite			Endopodite		
				I	II	III	I	II	III
I	outer inner	CC	1p′ 1P′	1p′	3p′ 6P′		1p′ 6P′	1P′	1P′
II	outer inner	CC	1s CC	pc, 1H	1H 1P	2H 4P, 1H	c, L 1P	c, L 1P	3H 3P
III	outer inner	CC	1s CC	1H	1H 1P	2H 5P, 1H	c, L 1P, cc	c, L 1P, cc	3H 2P
IV	outer inner	CC	c, 1s	1s	1s	1s 3–4s	c 1s, cc	c 1s	3H
V	outer inner		1s	4h CC					

First exopodite joint of second legs finely pectinate on outer margin. First two endopodite joints of second and third legs furnished with a small crescentic lamella on outer margin besides with fringing hairs. Terminal joint of fifth legs with several irregular rows of short spinules on inner surface instead of three hairy rows of holotype. All of plumose spines present on first legs thickly surrounded by fine hairs on all sides and extending entire length, whereas those on the other legs with double row of hairs. Simple spines on second and third legs pectinate on one side and those on exopodite, for the greater part, carrying a subterminal, thin, filiform prolongation. Terminal spines on the endopodite of fourth legs also pectinate; inner member of them extraordinarily elongate, attaining thrice the length of the other and with thin fragile tip.

Male: Allotype. Much smaller than female in size. Total length 1.41, carapace 0.39×0.49, second thoracic segment 0.18×0.35, third segment 0.11×0.32, fourth segment 0.13×0.25, fifth segment 0.10×0.23, genital segment 0.17×0.18, first abdominal segment 0.10×0.13, second segment 0.11×0.13, third segment

Fig. 5. *Taeniacanthus longichela* YAMAGUTI et YAMASU. A–I, female; A, first leg; B, exopodite of same, posterior view; C, second leg; D, outer spine on exopodite of same leg; E, third leg; F, fourth leg; G, fifth leg, dorsal view; H, same, ventral view; I, last segment with caudal rami; J–K, male; J, fourth leg; K, fifth leg. A–C, E–I ×155; D, J, K ×305.

0.10×0.11 (all in mm).

Carapace wider than long, semicircular in outline, having widely round free margin and nearly straight hind border. Frontal lamina relatively wider than in female, postero-lateral corners angular and median region forming a narrowed, very short neck. Thoracic segments successively narrowing from before backward, discontiguous on the sides and separated one from another by straight borders. Second segment quadrilateral; succeeding three shorter than the second, subequal to one another in length and with sides triangularly produced at the bases of limbs. Sixth segment again longer than the preceding, but narrower, as long as the second segment and about as long as its own width. It is barrel-shaped, having somewhat convex sides. Abdomen composed of three subequal segments; first two of them quadrate, only slightly shorter than wide, whereas last segment insensibly tapering backward and with almost truncate caudal end.

First antennae as in female, but somewhat longer in relation to the size of carapace. Maxillary hook more strongly incurvated than in female. Second maxillipeds subcheliform, having the distal joint folded back over the proximal. Distal joint curved like a sickle, attaining to the base of proximal joint when closed, finely pectinate on distal half of its inner border and carrying a sharp bristle near its base. Proximal joint dilated in a fusiform and furnished along inner border with two longitudinal, pectinated or tuberculated lines which interpose a narrow flattened, smooth area. Fourth thoracic legs somewhat different from those of female in their armatures as indicated in Table IV.

Table IV. The armature on the fourth and fifth legs of the male of *Taeniacanthus longichela* YAMAGUTI et YAMASU

Leg	Border	Sternal plate	Protopodite	Exopodite			Endopodite		
				I	II	III	I	II	III
IV	outer			1s	1s	1s		c	c, 3H
	inner				1H	1H, 3s	1P	1P	
V	outer		1s	4H					
	inner			cc					

Exopodite of this pair of legs ends in blunt claviform apex and carries a long simple, fragile spine on each of second and third joints on inner border. Inner member of terminal spines of endopodite relatively much longer than in female and with aciform apex. Inner spines on two proximal joints better developed than in female and doubly edged with sparse hairs. Fifth legs also with relatively stouter accessory spines and with hairy rows on the surface instead of spinules. Caudal rami end in relatively longer terminal spines.

Remarks: Besides from the fish named above, the present parasite was

recorded from *Aluteres monoceros* (L.) by YAMAGUTI and YAMASU.

Genus *Lepeophtheirus* NORDMANN

Lepeophtheirus hastatus sp. nov.

(Figs. 6 and 7)

Occurrence: Two females, each with egg strings, were found by myself intermingling with the preserved specimens of *Lepeophtheirus nordmanni* M. EDWARDS, which were taken from the body surface of *Mola mola* (L.) at Seto by Dr. F. UTINOMI, March 5, 1953.

Holotype: Female. Body somewhat larger in size than in *nordmanni*, 12.2 long, carapace 7.69×6.50, fourth thoracic segment 0.93×2.33, genital segment on the midline 2.33 long, same, including posterior lobes 2.91 long, 2.91 wide, abdomen 1.46 long, first segment 0.39×0.75, second segment 1.07×0.79, egg string 22 (all in mm). Color in alcohol yellowish white, carapace and genital segment sparsely scattered with brownish pigment spots.

Carapace convex dorsally, oval in outline, only slightly narrower anteriorly than posteriorly. Frontal plates slightly arched, insensibly notched on the median, about half as wide as carapace and not prominent. Sides of carapace widely round, median lobe truncate on posterior border and lateral lobes well round. Lateral sinuses small, ovate and with narrow posterior entrance. Longitudinal ribs of H-shaped dorsal suture divide the carapace equally into central and a pair of lateral fields. They run parallel and straight in their anterior halves, diverge in their posterior halves and incurvate near extreme ends. Transverse rib placed behind the centre of carapace and arched forward in the middle. Eyes lie on the midway between this rib and frontal margin. Lateral flanges narrow and associated with a row of short spinules; those of frontal plates again narrower.

Fourth segment less than one third as wide as carapace, a quarter as long as it own width, narrowed in front into a short neck, widely curved on hinder border and blunt on either side. Genital segment about one third as long as carapace on midline, two fifths as long in lateral region and as wide as its own length in the latter region. The segment narrows in front to join the preceding segment, abruptly widens just behind and again diminishes in width gradually backward, thus showing a well-arched sides; post-lateral angles are produced into a pair of blunt, linguiform lobes, which extend back on either side of abdomen ending in front of its middle. Abdomen rod-like in shape, three quarters as long as genital segment, half as wide as long, of uniform width and somewhat indistinctly segmented at the anterior quarter of its length; caudal end V-shaped.

First antennae relatively slender; apical joint claviform, tipped with

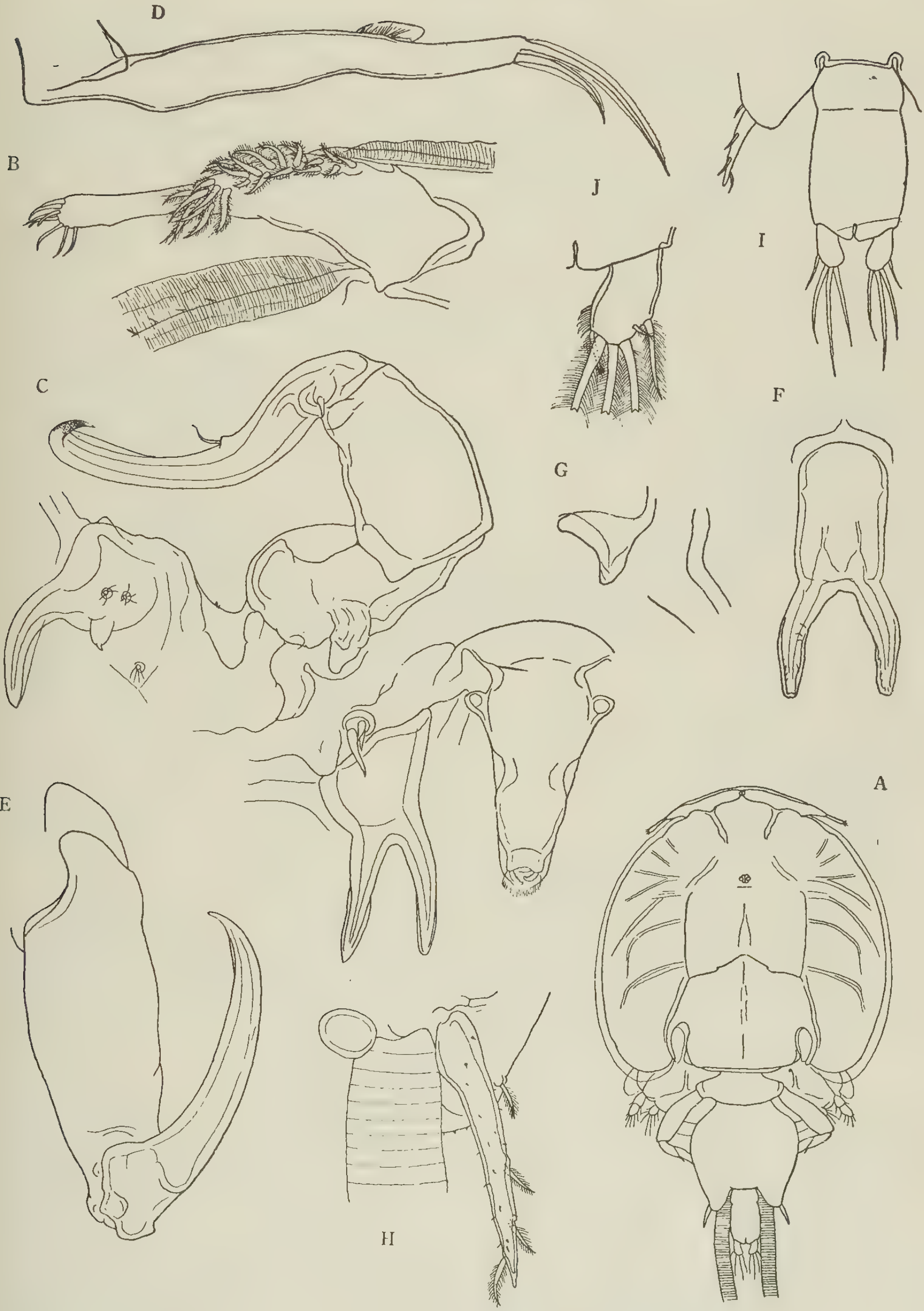

Fig. 6. *Lepeophtheirus hastatus* sp. nov., female. A, dorsal view; B, first antenna, ventral view; C, second antenna, mouth tube and two maxillae; D, first maxilliped; E, second maxilliped; F, sternal fork; G, accessory spine of sternal fork; H, fifth and sixth legs; I, abdomen with postero-lateral lobe of genital segment, dorsal view; J, caudal ramus. A ×5.2; B ×43; C–H, J ×37; I ×17.

several simple hairs as in ordinary case; basal joint longer than the apical, comparatively slender, attenuating toward the end and fringed along anterior border with double row of plumose spines. Second antennae stout. First joint with a bluntly pointed, finger-like posterior spine. Second joint columnar. Third joint aciform, longest of all and curved twice. It shows in its basal part a gentle backward curvature, while in apical part a much stronger ventral curvature in the form of a hook, and carries two short spinules, one at the base, the other for some distance distally, and a narrow membraneous rim just behind the apex. First maxillae consist of a falcate, bluntly pointed apex with a narrow inner rim and a quadrate base which bears on posterior side a short mammiform accessory branch, tipped by a rudimentary spinule, and on the surface two tubercles surmounted with tiny hairs; a similar tubercle lies on the sternum just behind this pair of maxillae. Mouth tube is elongate conical, enclosing styliform mandibles with finely serrated, curved apex. Second maxillae are bifurcate and composed of trapezoid base and two subequal, bluntly pointed, posteriorly directing branches which are doubly edged with narrow rim. Apical joint of first maxillipeds has two unequal claws, doubly rimmed with finely serrated membrane, and a crescentic accessory lamina locating somewhat distally to the centre of joint. Second maxillipeds strongly built; first joint fusiform, relatively narrow, about one third as wide as long and second joint well-curved like a sickle, pointed at its tip and reaching the base of the first. Sternal fork has a quadrilateral base, which is longer than wide, and its two divergent branches, apices of which incurvate so as to direct straight backward, have narrow rims and end bluntly; it is associated with a pair of short triangular processes situated on the sternum at a short distance laterally.

First legs furnished with a blunt, thumb-like rudiment of endopodite. In second legs, first joint of exopodite longer than the rest two combined together and second joint of endopodite expanded into a lunular lobe on the outside

Table V. Details of the armature on the legs of *Lepeophtheirus hastatus* sp. nov.

Leg	Border	Sternal plate	Protopodite		Exopodite			Endopodite		
			I	II	I	II	III	I	II	III
I	outer		1p		1rh	3H				
	inner				c	3P, 1p				
II	outer	f	1rh	f	f, 1H	1H	2H, 1Q	c	c	
	inner		1P	f	c, 1P	c, 1P	c, 5P	1P	c, 2P	c, 6P
III	outer	f	1p, f			c, 1h	c, 3h		c	
	inner		1P, 2rh, f		1H′, 1P	c, 1P	c, 4P	1P	c, 6P	
IV	outer		rh, 1h, 1p		rh, pc, 1h	pc, 1h	pc, 1h, 2H			
	inner									

and into a quadrate lobe on the inside. Exopodite of third legs three-jointed, with basal joint strongly reduced; their endopodite less than half as long as exopodite, two-jointed and having basal joint similarly reduced. Both the rami attached to the basal apron closely adjoining each other, but inserting between them a small semicircular expansion of the apron. Fourth legs four-jointed; first joint a little shorter than the rest three combined together, but thicker. Armatures on those pairs of legs are diagrammatically indicated in Table V.

Fig. 7. *Lepeophtheirus hastatus* sp. nov., female. A, first leg; B, second leg; C, third leg; D, exopodite of same, posterior view; E, fourth leg. ×37.

Apical non-plumose spines on terminal joint of first legs are accompanied at their bases each with a small lunular, finely pectinate lamina; of them, the inner two are doubly edged with pectinate rim. External spines on exopodite joint of second legs bear along two opposite borders narrow rims with entire margin; rims on second and third spines of third joint are much broader. Basal hook of exopodite of third legs is curved at right angles, sharply pointed and has narrow rims in apical region and a tiny hair at outer angle of the curved point. First two joints of fourth legs carry a number of tubercles, surmounted by a tiny spinule, on outer margin as well as on surface. Second to fourth joints are rimmed along outer border with a narrow pectinate membrane, which is confined to the distal half of the border in the second. Inner two spines at the tip of fourth joint are longer than the rest, which is as long as the ones on second and third joints. All of them are armed along their sides either with pectination or with pectinate rims and associated at the base each with a crescentic, pectinate lamina. Fifth leg rudiments are represented by short plumose spine situated on outer margin of the posterior lobes of genital segment. Sixth legs locate more anteriorly and more internally than the fifth and are placed just outside the attachment of egg strings. They are long, styliform, sharply pointed rods, directing postero-laterally, and carry two short plumose spines on outer border, a similar, subterminal one on inner border and very tiny scattering spinules on the borders as well as on the surface. They are distinctly jointed with the segment.

Caudal rami are rather small in size, somewhat internally turned at their apices and terminate in three longer plumose spines which are accompanied with two similar, but far shorter, unequal spines on the outside and with another on the inside. Inner border of the rami is ciliated on distal half.

Remarks: In the constitution of general body and of appendages, the new species closely resembles *L. nordmanni* which likewise occurs on *Mola mola* (L.), but it distinctly differs in the points enumerated below. The first maxillae bear an inner accessory branch, tipped by a rudimentary spinule. Branches of sternal fork are shorter than in *nordmanni* in relation to the length of its base. The first legs have terminal spines unforked. The fourth legs are relatively slenderer and longer than in *nordmanni*. Genital segment has the postero-lateral lobes as in this species, but is different in being wider anteriorly than posteriorly. The rudiments of the sixth legs are slender and styliform instead of being short and lamellar, and projecting for some distance beyond the end of the genital segment. The abdomen has parallel sides and is indistinctly segmented.

In the possession of the postero-lateral lobes on the genital segment and the styliform rudiments of the sixth legs, the new species is also close to *L.*

spinifer KIRTISINGHE recorded from Ceylon. The former is different, however, from the latter in the second maxillae being unforked, in the fourth legs being broader and more robust, and in the configuration of the genital segment. Finally, *hastatus* is close to *Gloiopotes crassus* WILSON et BERE in the general body structure, not to mention of the absence of dorsal plates in the fourth segment. It differs in that the fourth legs carry well-developed spine on the second joint and in that the sixth legs are distinctly jointed with the genital segment and not represented by mere processes of the ventral surface.

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Two New Parasitic Copepods belonging to a New Genus *Prochondracanthopsis* (Chondracanthidae)

(*With Four Text-Figures*)

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Two new parasitic copepods to be described here were found clinging to the gills of fishes collected in Japanese waters. They agree with the members of the Family Chondracanthidae in the general constitution of the body as well as in the details of the mouth parts, and the shortness of their neck region tells that they fall within the confines of the Subfamily Chondracanthinae. They are yet different from all the other genera of the Subfamily in that two pairs of thoracic legs, which are ordinarily represented by large-sized, bilobed, fleshy processes, are extremely reduced and nothing but mere stumps of the chitinous covering of the body. This is an important difference and enough to warrant the erection of a new genus for them.

Genus *Prochondracanthopsis* gen. nov.

Gill parasite. Chondracanthidae, Chondracanthinae.

Female: Body divisible into two swellings: head and trunk. Head composed of cephalic and first thoracic segments. Second and third segments form a short, narrow neck connecting head with trunk. Trunk voluminous, lacking constriction in the middle of its length. Genital segment and abdomen represented by a small pyramidal process attached to caudal end of trunk. Antennules fleshy processes. Antennae hook-like, strongly chitinized, serving as principal organ of prehension. Mandibles falcate. Maxillulae round lamellae. Maxillae two-jointed, apical joint falcate. Maxillipeds three-jointed, with apical joint unguiform. First two pairs of thoracic legs very rudimentary, represented by tiny uni- or biramous laminae with or without setae. First pair located just behind maxillipeds and second pair on the border between neck and trunk. Rest limbs absent. Caudal rami present, but rudimentary. Egg cases packed with multiseriate eggs.

Male: Dwarf. Attached to the body of female. As in other chondracanthids in structure. Head including segments up to first thoracic, voluminous. Succeeding segments form much narrower trunk with or without distinct metamerism. At least two pairs of thoracic legs, but in a rudimentary condition.

Caudal rami present.

Type species: *Prochondracanthopsis quadricornutus* sp. nov.

Prochondracanthopsis quadricornutus sp. nov.

(Figs. 1 and 2)

Occurrence: Two females, each associated with a male, were found clinging to the gills of *Suruga fundicola* JORDAN et SNYDER taken off Tyôsi, Tiba Prefecture, by myself, June, 3, 1942.

Female: Holotype. Body brownish in alcohol, total length from head to abdomen 1.75, same from tip of antennule to end of egg case 3.23, head and neck 0.58×0.65, trunk 1.15×0.63, genital segment and abdomen 0.15×0.15, egg case 1.47×0.38 (all in mm).

Head occupying about a quarter of entire length, wider than long, cordiform in dorsal view, narrowing backward, and widely round on fore margin, though somewhat wavy. In lateral view, it is most highly swollen behind the fore margin, to which the surface rapidly declines. On ventral side, it is produced at fore end on either side into a pair of round swellings and at hinder end into another pair of blunt, columnar, postero-laterally directing processes. Neck short, narrower than half the widest region of head and continuing to head and trunk without distinct demarcation. Trunk voluminous, only a little wider than half the length, cylindrical, of uniform width and thickness, and not constricted in the middle; both fore and hinder ends well round. Genital segment and abdomen form a small conical process present on caudal surface of trunk and ending in blunt apex. Egg tubes sausage-shaped, packed with multiseriate polygonal eggs.

First antennae fleshy, present at extreme fore end of head; each of them forked from the very base into longer and shorter, cylindrical branches with blunt apices; longer branch directed laterally, while shorter one anteriorly. Second antennae relatively small in size, but strongly chitinized and curved in the form of a sharply pointed hook. Oral aperture removed as far backward as the hinder end of head and placed between the posterior pair of its processes. Labrum distinct, non-tuberculated. Mandibles of small size, with serrated border and filiform apex. First maxillae represented by oval laminae tipped by a single spine. Second maxillae two-jointed; apical joint curved like a sickle and carrying a sharp tooth on inner border; endopodite small, ending in spiniform apex. Maxillipeds better developed than foregoing limbs, three-jointed; second joint bending over the first, and the third unguiform. Two pairs of thoracic legs extremely reduced and represented by tiny, irregular-shaped laminae on the ventral surface of the neck. First pair placed just behind the bases of the

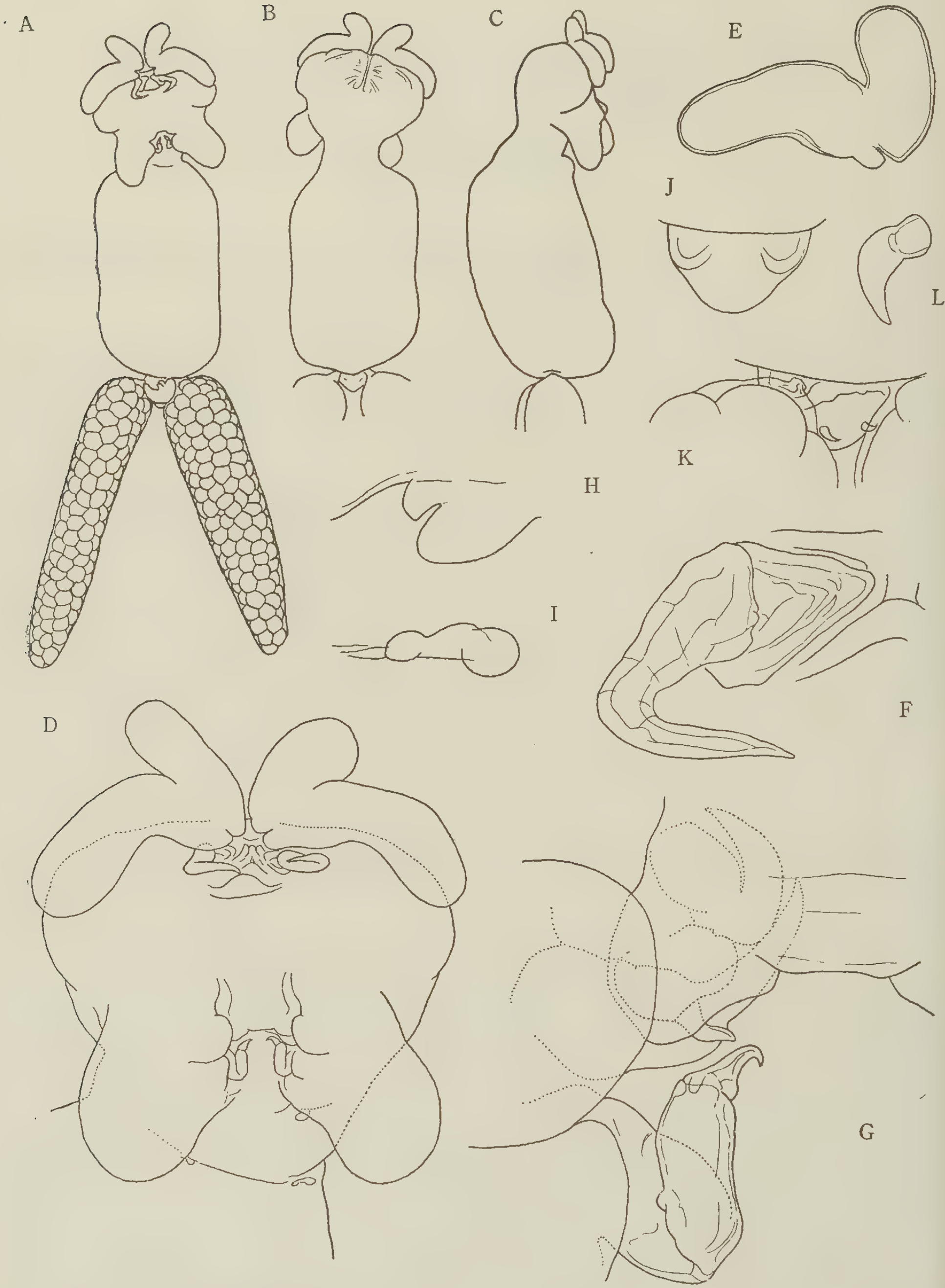

Fig. 1. *Prochondracanchopsis quadricornutus* gen. et sp. nov., female, holotype. A, ventral view; B, dorsal view; C, lateral view; D, head, ventral view; E, first antenna; F, second antenna; G, oral region, showing appendages from mandible to maxilliped; H, first leg; I, second leg; J, abdomen, dorsal view; K, same, ventral view; L, caudal ramus. A–C ×27, D, E ×83, F ×340, G-I ×520, I-L ×120.

posterior processes of head and second pair at the junction between neck and trunk. (In the paratype, the right member of the first pair is an oval, undivided lamina and the left member and the second pair are bilobed laminae.) They are lacking in fringing hairs. Rest of the limbs entirely absent. Caudal rami tiny, curved in unguiform, acuminating to the tip and without hairs.

Male: Allotype. Dwarf. As in other chondracanthids in general constitution. White in color, length 0.28, depth of carapace 0.12, length of head along ventral side 0.11, depth of trunk 0.06, its length along ventral side 0.10 (all in mm).

Body curved ventrally. Head swollen, trunk cylindrical, without showing distinct metamerism. First antennae filiform, four-jointed; second joint longest of all and fourth joint tipped by a few setae. Second antennae hook-like. First maxillae end in two spinules. Thoracic legs are two pairs of oval laminae present at fore end of the trunk. Caudal rami filiform, without setae.

Fig. 2. *Prochondracanthopsis quadricornutus* gen. et sp. nov. A, male, allotype, lateral view; B–D, female, paratype; B, second maxilla; C, mandible; D, two pairs of thoracic legs in situ. A ×340, B, C ×520, D ×170.

Remarks: The female of the present species is nearly allied to the members of *Prochondracanthus* YAMAGUTI in that the trunk is cylindrical and not subdivided by a lateral constriction, and in that two pairs of thoracic legs are not developed into bifurcate fleshy processes. It can, however, be discriminated from this genus by the forked antennules and by having a pair of ventral processes outside the maxillipeds and by the possession of legs so much reduced as to be easily overlooked, instead of lamellar, richly setose, larger-sized pairs of the genus. In the uncontracted trunk which lacks any accessory processes, the new species resembles *Humphreysia* LEIGH-SHARPE and *Schehrazarde* LEIGH-

Sharpe also. It agrees with the former of these again in the bifurcate antennules and with the latter in the rudimentary legs. *Humphreysia*, however, has far better developed legs which are distinctly bilobed processes as in other chondracanthids and *Scheherazarde* retains only a single pair of legs and has the antennules undivided and the neck extraordinarily prolonged.

Prochondracanthopsis bicornutus sp. nov.

(Figs. 3 and 4)

Occurrence: Four females, each associated with a male, were found by myself on the gills of *Owstonia totomiensis* Tanaka taken off Owase, Mie Prefecture, December 9, 1952. The females cling to the gill filaments lengthwise by the aid of the second antennae, directing their caudal ends toward the free ends of the filaments, and attach to the gill near its free margin. The male adheres to the abdomen of the female.

Female: Holotype. Color in preservative white. Body plump, 1.60 long, head $0.57\times0.84\times0.65$, neck $0.10\times0.40\times0.24$, trunk $0.86\times1.27\times0.74$, abdomen $0.08\times0.18\times0.18$. Egg cases burst.

Head about one third the entire length, wider than long, transversely ovate and evenly convex on dorsal side. Fore margin arcuate and produced on each side into a short blunt, forwardly projecting process. Ventral surface more or less uneven, elevated at the hinder end in a bulge, at whose apex oral aperture opens, and from which the surface declines vertically downward. Neck half as wide as head, short, distinctly bordered from head and trunk on dorsal side and from the latter on ventral side by a shallow transverse wrinkle. Trunk voluminous, twice as long as head, a quarter wider than long, more or less quadrilateral and lacking lateral constriction. Dorsal side evenly convex, somewhat arched in front and widely V-shaped behind. Ventral side depressed, more or less uneven on the surface. It has three pairs of low, antero-posteriorly arranged swellings; first pair situate at fore end, forming angularly round shoulders, second pair lie just behind and third pair, the largest, lie at hinder end and give the surface a bilobed appearance by the insertion of a depressed triangular median area. Two sides evenly curved. Genital segment and abdomen constitute a small round tubercle locating at caudal end of the trunk.

First antennae slender, elongate, projecting sidewise and indistinctly jointed near their blunt end, where they bear a few short hairs. Second antennae short, hook-like, with pointed end. Oral aperture removed from the antennae backward for a considerable distance. Labrum distinct, emarginate on the median and without marginal tuberculation. Mandibles ensiform, with serrated blade. First maxillae oval lobes, with spiniform accessory prolongation. Second

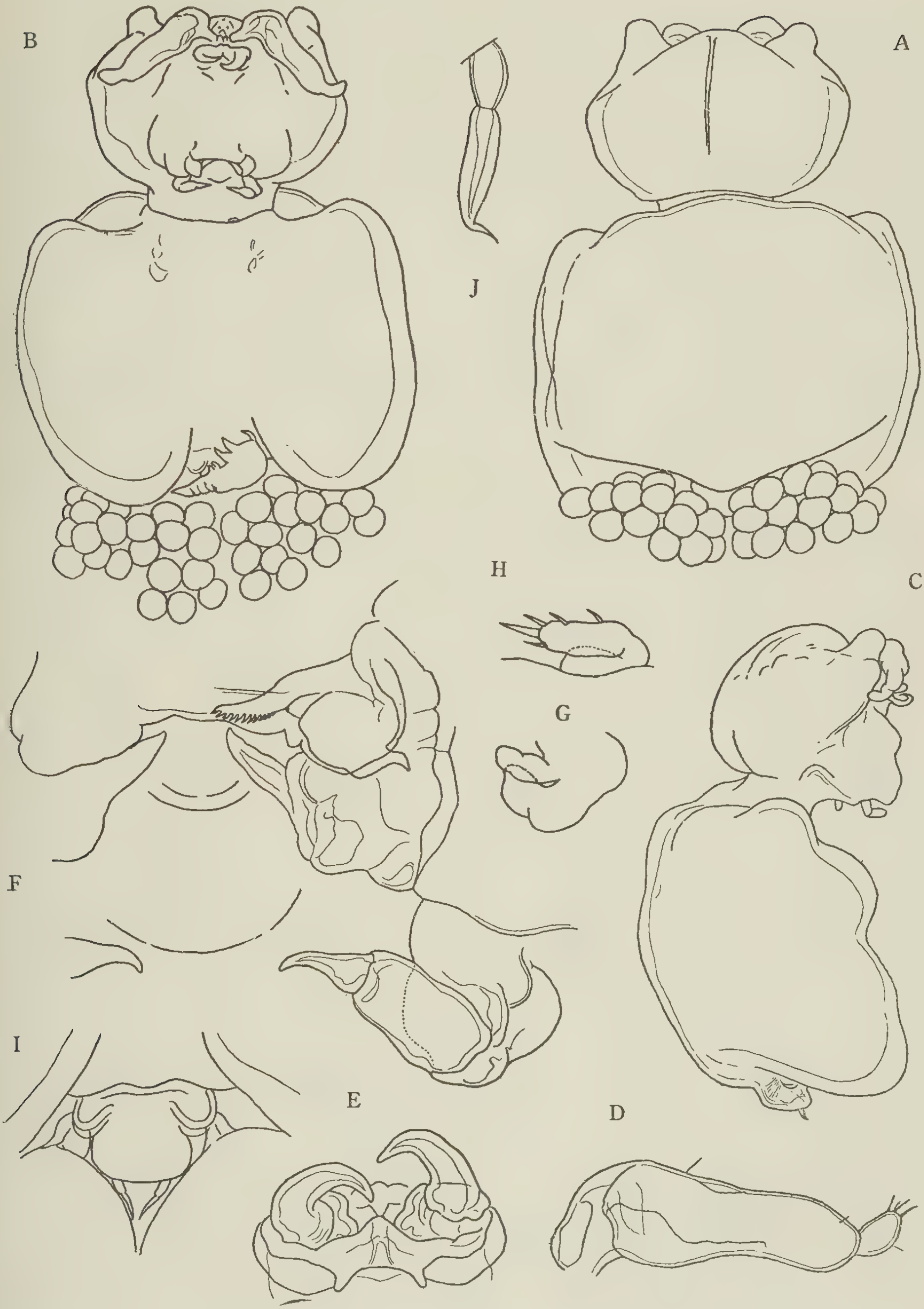

Fig. 3. *Prochondracanthopsis bicornutus* sp. nov., female. A, dorsal view; B, ventral view; C, lateral view; D, first antenna; E, second antenna; F, oral region, showing the appendages from mandible to maxilliped; G, first leg; H, second leg; I, abdomen, ventral view; J, caudal ramus. A-C ×41, D ×120, E ×170, F, J ×340, G, H ×520, I ×85.

maxillae composed of broad thick base and ensiform apex without marginal serration; endopodite not discernible. Maxillipeds as in the previous species, ending in unguiform apex. First pair of legs present just behind the maxillipeds, very rudimentary, being represented by tiny, bilobed, non-setaceous laminae. Second pair retained only on the left; this leg situated at the junction between neck and trunk, uniramous and bearing a few marginal spinules. Right leg and succeeding pairs entirely absent. Caudal rami very tiny, arising from the end of abdomen, and consisting of short peduncle and broad, acuminating terminal spine. Egg cases burst, but packed with multiserial round eggs.

Male: Allotype. Dwarf. Total length 0.30, head 0.15×0.15×0.15, second thoracic segment 0.05×0.11×0.08, third segment 0.03×0.09×0.06, fourth segment 0.03×0.07×0.05, fifth segment 0.02×0.06×0.05, genital segment 0.02×0.06×0.04,

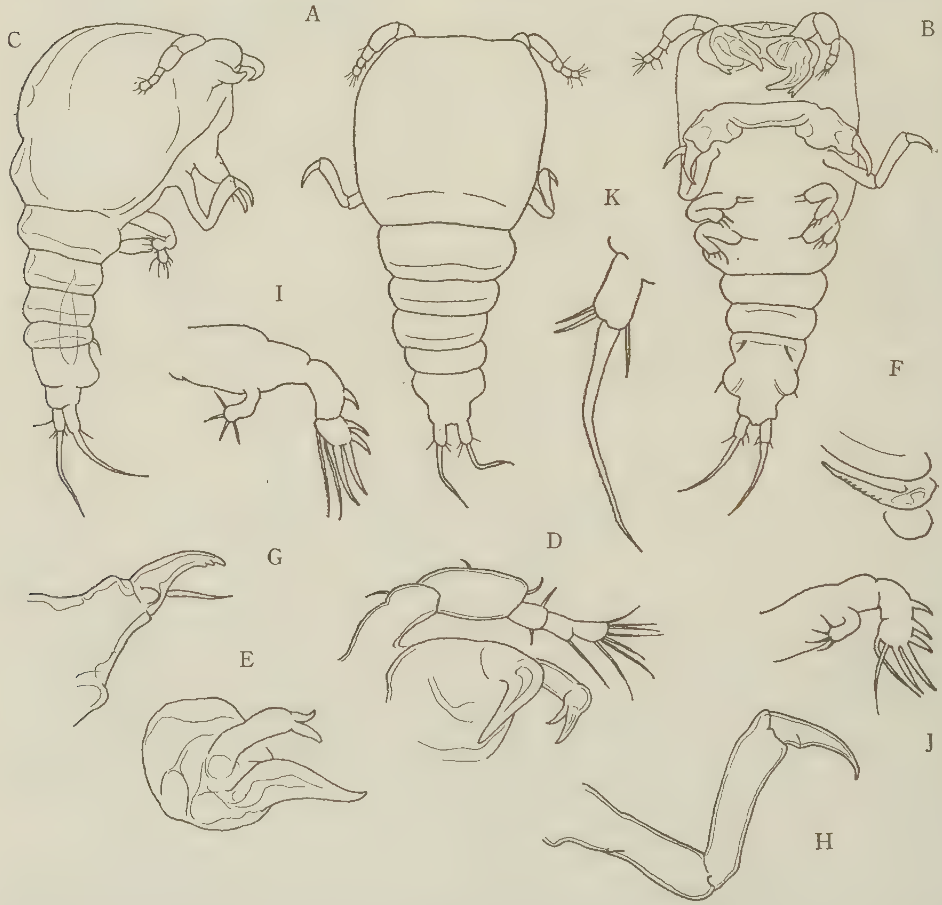

Fig. 4. *Prochondracanthopsis bicornutus* sp. nov., male. A, dorsal view; B, ventral view; C, lateral view; D, first and second antennae; E, second antenna; F, labrum, mandible and first maxilla; G, second maxilla; H, maxilliped; I, first thoracic leg; J, second thoracic leg; K, caudal ramus. A–C ×170; D–K ×520.

abdomen $0.01 \times 0.03 \times 0.03$, caudal rami inclusive of terminal hair 0.08 long.

Body swollen in cephalic region, successively tapering backward. Head occupying half the length of body, as long as wide, roughly quadrilateral and strongly convex on dorsal side, being higher anteriorly than posteriorly. Fore and hinder borders straight, two sides insensibly curved. Consecutive thoracic segments distinct one from another and diminishing in length and width from before backward a little by little. Genital segment with a pair of genital swellings on ventral side and indistinctly bordered from abdomen, which is abruptly narrower and shorter.

First antennae far apart from each other at their bases, five-jointed; first and second joints subequal, much longer and thicker than the rest three; first to fourth joints sparsely setose and last joint tipped by a number of setae. Second antennae close to each other on the midline, with broad base and acuminating, hook-like apex, and carrying an accessory tubular ramus ending in two unequal claws. Mandibular blade serrated. First maxillae tuberculiform, without spine. Second maxillae have thick broad protopodite, ensiform exopodite with rudimentary serration and simple, setiform endopodite. Maxillipeds longer and slenderer than the preceding limbs, three-jointed, geniculate and with last joint sharp and unguiform. First pair of thoracic legs issued from the head at its posterior end and second pair from the first free (second thoracic) segment. Both pairs biramous; protopodite more or less prolonged, transversely oriented, carrying a two-jointed exopodite terminally and a smaller unjointed endopodite subterminally. Exopodite armed with external spine on first joint and with four external spines and two internal setae on second joint. Endopodite with four feeble hairs at the apex. Third and fourth thoracic segments limbless, fifth with a pair of spinules instead of limbs and sixth with finer hairs on the tops of genital swellings. Caudal rami tubular, ending in a long stout spine which is accompanied at the base with two shorter external and one internal setae.

Remarks: The female of the present species bears a certain resemblance to *Blias prionoti* KRØYER (=*Tucca* sp. PEARSE, *Tuccopsis pinguis* PEARSE) in its appearance, especially in its voluminous trunk which is devoid of lateral constriction and in the lack of forked, fleshy thoracic legs. It is distinguished from *Blias*, before everything, by that the antennal pairs are well differentiated and not replaced by bifurcate, peg-like holdfast organs (according to CAUSEY 1955). It is different also in the much rudimentary condition of the thoracic legs which are far better developed in *Blias*. By the way, this genus had been considered as lacking the legs until it was submitted to a careful revision by CAUSEY.

The present species is discriminated from *quadricornutus* by the unforked antennules of the female, by its broader trunk and by the distinct metamerism

of the male body.

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Parasitic Copepods of Fishes from the Eastern Pacific

(*With six Text-figures*)

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Last year, I made a report on a number of copepod species which were parasitic on the fishes from the Eastern Pacific on the basis of the specimens submitted to me for my study by Dr. W. L. KLAWE of the Inter-American Tropical Tuna Commission. He was kind enough to continue thereafter to supply me with further materials. The present article deals with the forms which were not included in the last report.

Before entering into the description of the species, I wish to express my sincere thanks to Dr. W. L. KLAWE for his great help to my study.

Genus *Caligus* MÜLLER

Caligus bonito WILSON

(Fig. 1)

WILSON 1905, Proc. U. S. Nat. Mus., **28**: 589-594, Pl. 13, Figs. 150-153, Text-figs. 5, 12-15, 29, 30, 35, 37, 38, 40-45; 1932, 407-408, Fig. 255; BRIAN 1935, 188-191, Fig. 14; YAMAGUTI 1936, 8-9, Pl. 5, Figs. 69-71, Pl. 6, Figs. 72-85; 1953, 4; NUNES-RUIVO 1956, 6-11, Fig. 2.

Occurrence: Eight females and two males were collected on the outside and inside the buccal cavity of *Sarda chilensis*, off Ocean Beach, near San Diego, California, by W. L. KLAWE and P. N. SUND, 22 September 1959.

This species, the diagnosis of which was adequately given by WILSON, was described over again by subsequent authors, and there may be no need of repetition.

Female: Length of the largest female 6.77, carapace 2.61×2.56, fourth thoracic segment 0.39×0.89, genital segment, on the midline 2.05 long, same, on the side 2.28 long, 1.56 wide, abdomen 1.72 (all in mm). Only one female carries a single egg case. The shape of the female genital segment and its size proportional to that of the carapace are somewhat variable. In the specimens collected, the ratio between the length of the free segments to the same of the carapace varies from 1.43 to 1.76.

Male: Length of the larger male 6.01, carapace 2.94×2.61, fourth thoracic segment 0.28×0.72, genital segment 1.22×0.78, abdomen 1.22 long, first segment 0.50×0.39, second segment 0.72×0.42 (all in mm).

Hosts hitherto recorded: *Katsuwonus pelamis* (=*Gymnosarda pelamis*, *Euthynnus pelamis*), *Sarda sarda*, *S. chilensis*, *Lutianus griens*, *Mugil cephalus*, *Oligoplites saurus*, *Pomatomus saltatrix*, *Scomberomorus cavalla*, *S. maculata*.

Distribution: The Atlantic coast of North and South America and of Africa, the Mediterranean, the Pacific coast of North America and Japan.

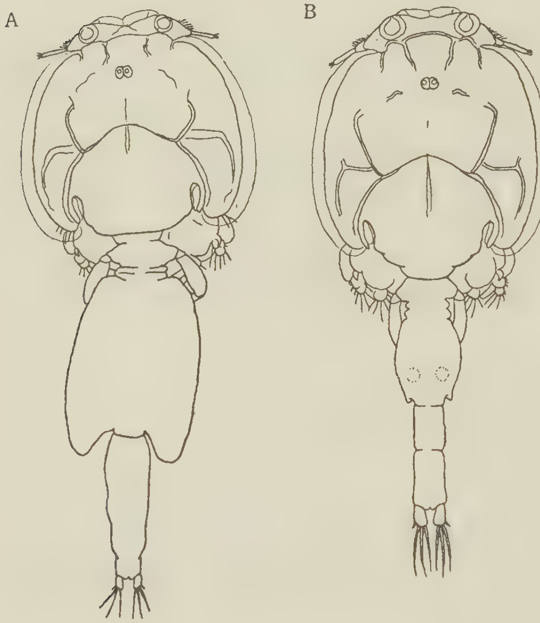

Fig. 1. *Caligus bonito* WILSON. A, female, dorsal view; B, male, dorsal view ×11.

Fig. 2. *Lepeophtheirus longiabdominis* sp. nov., female. ×11.

Genus *Lepeophtheirus* NORDMANN

Lepeophtheirus longiabdominis sp. nov.

(Figs. 2 and 3)

Occurrence: Four females were taken from the outside surface of *Cynoscion nobilis* (white sea-bass), off La Jolla, California, by W. L. KLAWE, at the end of August 1957.

Holotype: Female with an egg string. Total length 8.61, carapace 3.60×3.16, fourth thoracic segment 0.56×1.22, genital segment 2.50×2.00, abdomen 1.95×0.72, egg string 6.92 (all in mm). Coloration dark yellowish brown in formalin, with scattering black pigment spots all over the dorsal surface.

Carapace ovate, longer than wide. Frontal plates less than two thirds as wide as carapace, widely curved on margin, with a slight median notch and

ending laterally in blunt linguiform lobe. Sides of carapace widely round, terminating posteriorly in a narrow blunt lobes and bearing a slight incision at anterior one third of the entire length. Postero-median lobe nearly truncate, but with a short median projection and angularly round at either corner. Longitudinal dorsal sutures divide the carapace into a broader central and two far narrower lateral areas. They make a curve slightly convex outward in their anterior halves, from whose fore ends a short transverse suture runs medially; posterior halves diverge from each other, but curve inward near hinder ends. Horizontal suture traverses the carapace at its centre, making an anteriorly arched, broad V-shape. Eyes locate just in front of the anterior transverse sutures.

Fourth thoracic segment two fifths as wide as carapace, less than half as long as its own width, constricted both in front and behind and forming blunt, narrowed lateral lobes to receive the bases of legs. Genital segment about three quarters as long as carapace, longer than wide, narrower anteriorly than posteriorly, with sides divergent backward and posterior border forming a pair of round lateral lobes which protrude only slightly beyond the median region. Abdomen one-segmented, elongate, about three quarters as long as the preceding segment, almost uniform in width and diagonally cut at caudal end on each side.

Apical joint of first antennae short in relation to the length of basal joint and tipped with several short bristles; the latter joint attenuating to the tip, with two marginal rows of relatively sparse spines, which are, for the greater part, deprived of fringing hairs. Second antennae robust; first joint short, with a posterior process, attenuating to the blunt tip, second joint relatively short and thick, and third joint elongate, slender, curved near the apex like a hook and supplied with two short hairs, one near the base and the other at some distance distally. First maxillae consist of an oval base, provided on the surface with two tubercles surmounted by tiny hairs and a slightly curved, blunt apex which is only a little larger than the posterior process of second antennae. Sternum just behind the first maxillae bears another hairy tubercle. Second maxillae have a triangular base, which issues two subequal, externally curved branches with blunt tips; exopodite rudiment of the maxillae carries three short thick spinules. Terminal joint of first maxillipeds is as long as the basal, carrying a small oval lamina about the middle and ending in two unequal claws with finely serrated borders. Branches of sternal fork incurvate, forming together a U-shape, are uniform in width and have blunt ends. Second maxillipeds are robust; palm is swollen into a fusiform; finger is bent strongly at the tip, reaching the middle of inner margin of palm, and bears a short accessory spine some distance in front of its base.

Fig. 3. *Lepeophtheirus longiabdominis* sp. nov., female. A first antenna, ventral view; B, second antenna and maxillae; C, first maxilliped; D, second maxilliped; E, sternal fork; F, first leg; G, terminal spines of same; H, second leg; I, external border of exopodite of same; J, third leg; K, exopodite of same, posterior side; L, fourth leg; M, tip of same; N, end of third segment of same; O, end of second segment of same; P, fifth leg rudiment, ventral view; Q, caudal ramus. A–F, H, J, L, Q ×47, G ×155, I, K, M–O ×110, P ×145.

First swimming legs furnished with a short, spine-tipped rudiment of endopodite. Both rami of third legs close to each other and placed at either lateral angle of basal apron; exopodite three-jointed, with basal joint rudimentary; endopodite two-jointed, having basal joint expanded outward in a crescentic lobe. Fourth legs four-jointed; first joint as long as rest joints combined together, but much broader; these latter of uniform width, longest in the middle joint, shortest in the apical, and bordered one from another by obliquely running boundaries. Armatures on the first four pairs of legs are listed in Table I.

Table I. Details of the armature on the legs of *Lepeophtheirus longiabdominis* sp. nov.*

Leg	Border	Sternal plate	Protopodite		Exopodite			Endopodite		
			I	II	I	II	III	I	II	III
I	outer inner		1p 1p		1rh c	3H, 1p 3P				
II	outer inner	f	1s 1p	f, 1p f, 1s	f, 1H c, 1P	1H c, 1P	2H, 1Q c, 5P	c 1P	c c, 2P	c c, 6P
III	outer inner	f	f, 1p 1P, f, 2s		1H′ 1P	c, 1h c, 1P	c, 3h c, 4P	c 1P	c c, 6P	
IV	outer inner		ss, 1p		1rh	pc, 1H	pc, 3H			

Non-plumose spines on terminal joint of first legs serrated on inner border and accompanied each with a finely pectinated lamina at their bases; inner two of them bifid. Outer spine on first two exopodite joints of second legs and first spine on third joint doubly edged with serration; the spine on first joint with a transverse row of short hairs at the base. Second spine of third joint with broad, finely striated flange on two opposite borders and third spine also with similar flange on outer border. Hook-like spine at the base of exopodite of third legs has three short hairs on outer border of basal part which is produced at the end into an oval lamina; terminal claw arises just behind this lamina, making an obtuse angle with the basal part, has a narrow external rim and ends in blunt tip. First joint of fourth legs bears a number of short scattering hairs on outer border and near the end; third and fourth joints are finely pectinate on outer border. Third and fourth joints are rimmed with pectination on outer border. Spine on third joint and outermost spine on fourth joint are

* Abbreviations used in Table: C, row of spinules; row of hairs; f, membraneous flange; H, longer simple spine; h, shorter simple spine; H′, hook-like spine; P, longer plumose spine; p, shorter plumose spine; pc, pectination; Q, longer spine hairy on one side, with membrane on the other side; q, shorter spine of similar nature, rh, rudimentary spine; s, solitary hair; ss, scattering hairs. Roman numerals indicate the numerical order of legs or their joints and arabian ones the number of spines and hairs present on them.

of same length and doubly edged with pectination or pectinate rim. Other spines on the latter joint are much longer than these and bear pectinate rim only on outer border. All of them are furnished with basal pectinate lamina. Fifth legs are represented each by a short plumose spine surmounting on a papilla which is present on the ventral surface of genital segment near each lateral angle. Sixth legs are foliaceous lamellae issued from the segment at its extreme end and just outside the attachment of abdomen; they carry four short plumose spines.

Caudal rami short, supplied with four long terminal plumose spines, outermost of which is somewhat removed from the others. They bear a tiny plumose spine at inner distal angle, another similar one in the region between the two outer members of terminal spines, and a row of short hairs on inner border.

Remarks: In the possession of broadly dilated genital segment, elongate abdomen and four-jointed legs on the fourth segment, the new species is nearly allied to *longipalpus* BASSETT-SMITH, *thompsonii* BAIRD (=*gracilis* CLAUS, *rhombi* KRØYER, *obscurus* T. SCOTT, *Cligus gracilis* VAN BENEDEN, C. *branchialis* MALM), *pollachii* BASETT-SMITH (=*innominatus* WILSON), *sturionis* (KRØYER) *and salmonis* (KRØYER) (=*stromii* (BAIRD), *uenoi* YAMAGUTI, *Caligus vespa* M.-EDWARDS).

The new species is distinguished from *longipalpus* and *thompsoni* by having unsegmented abdomen instead of two-segmented one, and from *pollachii* by the shape of genital segment as well as by that the second joint of the fourth legs is armed with a rudimentary spine. In the armatures of the fourth legs it is in accord with *sturionis* and *salmonis*. It differs from the former of these in having U-shaped sternal fork with blunt apices and in the configuration of genital segment. It is closest to the latter in the general character, but is much smaller in size. Postero-lateral lobes on the genital segment are not so well developed as in the latter and they carry the rudiments of the fifth and sixth legs, both of which are absent from *salmonis*. Further, another characteristic of the new species lies in the possession of the fourth legs which are stouter than those of any of the species compared above.

Other species of *Lepeophtheirus*, which possess an elongate abdomen, such as *unispinosus* PEARSE, *monacanthus* HELLER, *parvicruris* FRASER and *longiventris* YÜ et WU are all different from the new species in that the fourth legs are three-jointed.

Genus *Gloiopotes* STEENSTRUP et LÜTKEN

Gloiopotes hygomianus STEENSTRUP et LÜTKEN

(Figs. 4–6)

STEENSTRUP and LÜTKEN 1861, Vid. Selsk. Skrift. V R. Naturw.-Math. Afh. **5**: 363-364, Pl. 5, Fig. 9.

Occurrence: Two females and a male were obtained from the external surface of *Acanthocybium solandri*, off Cocos Island, by W. L. KLAWE, 3 December 1959.

Female: Body largely semitransparent and colorless in preservative; central region of carapace more or less whitish and genital segment with pinkish tinge originating in the oviducts containing eggs. Eyes brownish. Second antennae, second maxillae, claws of second maxillipeds and sternal fork dark brown at the apices owing to their strong chitinization. Outer spines on exopodite of second legs and basal hook on exopodite of third legs colored in brown. Apical spines of first legs horny, but paler in color, yellowish. Central bar of dorsal ribs of carapace and post-ocular ribs rather feebly chitinized, especially so in the former. Length from the top of head to the end of caudal

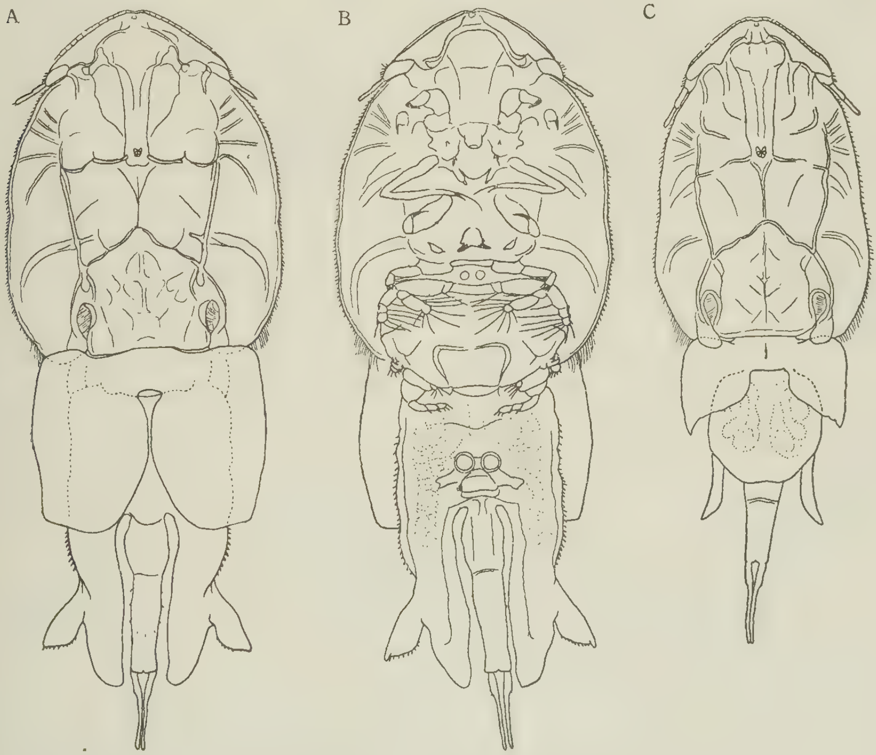

Fig. 4. *Gloiopotes hygomianus* STEENSTRUP et LÜTKEN. A, female, dorsal view; B, same, ventral view; C, male. A, B ×6.7, C ×9.

rami 13.66, carapace 6.61×5.45. Fourth segment, on mid-dorsal line 0.98 long, same, including dorsal plates 3.57×4.55, genital segment on mid-dorsal line 2.50 long, same, including posterior processes 5.89×4.01, calibre across lateral lobes of same 4.10 wide, posterior processes 3.39 long, abdomen 2.84 long, first segment 1.16×0.85, second segment 1.88×0.62, caudal ramus 1.60 long (all in mm).

Carapace longer than wide, somewhat tapering forward and strongly concave ventrally, its edges forming together with basal apron of third legs a sort of effective adhesive disc. Frontal plates two thirds as wide as carapace, protruding forward into a wide V-shape and fringed with a sparse row of tiny hairs, besides with very narrow membrane. Sides of carapace widely round, though more or less undulated, and edged with narrow flange and row of short hairs, which grow longer in the region of lateral lobes. Median lobe truncate on hind border. Lateral lobes hardly extend back beyond the median lobe and turn inward so as to enclose on either side of this a pair of oval sinuses. Each of them bears outside the sinus a membraneous lamella resembling an ear-lobe in shape and freely projecting outward over the dorsal surface, and in front a small triangular membrane, besides carrying ordinary membrane issuing inward from the outer border of the sinus. Dorsal ribs not so strongly chitinized as in other species of *Gloiopotes*. Transverse central rib arched forward in the form of a V. Longitudinal ribs are straight in their anterior halves, somewhat divergent toward the front and connected with each other at the fore end by a series of short horizontal ribs which are interrupted on the median owing to the insertion of peri-ocular field. Central region of carapace is divided in this way into three consecutive areas. Posterior halves of longitudinal ribs are divergent, but incurvated. Eyes small, lying on the level of anterior transverse ribs. Entire dorsal surface scattered by fine spinules each surmounting on a tiny tubercle.

Fourth thoracic segment provided with a pair of strongly enlarged dorsal plates, but much narrowed in its insertion to the carapace. Those plates about half as long as carapace, only slightly narrower in their combined width, quadrilateral in shape and almost entirely covering the main portion of succeeding segment. They are closely adjoining each other, but separated by a deep narrow median incision which reaches the hind border of that segment. The incision which is somewhat widened at fore end becomes strongly narrowed as it goes toward the rear, but it again enlarges, forming a funnelform crevice opening backward. Genital segment is wider than half the width of carapace, a little wider than its own length on the midline, and carries at hind end a pair of elongate processes. These extend backward on either side of and parallel with the abdomen, which they surpass a little, and they bear some distance in front of their blunt end a caudo-laterally projecting linguiform lobe with pointed

Fig. 5. *Gloiopotes hygomianus* STEENSTRUP et LUTKEN, female. A, first antenna; B, same, distal part of first joint; C, second antenna and maxillae; D, first and second maxillipeds; E, first leg; F, apical spines of same; G, tip of endopodite of same; H, second leg; I, third leg; J, two rami of same, posterior side. A, C–E, H–J ×37, B ×75, F,G ×110.

apex. The segment attains to six sevenths the length of carapace when those processes taken into account. Sides of the segment are nearly parallel with each other and edged with a row of short spinules, extending from a short distance behind the fore ends to the bases of lateral lobes. These lobes also bear a similar row along their hind border. Surface of the processes and the lobes is scatteringly covered with finer spinules. Abdomen is cylindrical, two-segmented, a trifle shorter than the paired processes of the previous segment. First segment is short, half as long as the second, but slightly wider, having curved sides. Second segment is uniform in width and truncate at caudal end. Both the segments are scattered over their surface with fine spinules.

First antennae feeble; basal joint rhombic in shape and fringed along anterior border with double row of plumose spines, some of which are transformed into acuminate foliaceous lamellae; distal joint slender, two-jointed and carrying a solitary hair on posterior border besides a few apical bristles. Basal joint of second antennae enlarged, quadrilateral and with a short conical posterior process; middle joint cylindrical, and terminal joint relatively broad, but attenuating toward the apex which is strongly curved so as to act as a robust hook, and carrying a thicker spinule at the base and a slenderer hair about the middle of the whole length. First maxillae short, composed of oval base, bearing a couple of feeble hairs, and strongly chitinized, sharply pointed apex, and associated just inside the base with a short finger-like process. Second maxillae nearly as large as the first, further enlarged at the base and having a slightly externally curved blade, which ends in blunt tip and is accompanied on the inside near the base with a tiny spiniform accessory branch; exopodite rudiment in front of them consisting of three spinules. First maxillipeds have joints slender and elongated; terminal joint is longer than the basal, tipped with slender claws of unequal lengths which bear narrow rim with entire margin, and close to whose bases a rudimentary spinule is present. They are accompanied inside their insertion to the sternum on either side with an internally directing rod-like, spine-tipped process. Second maxillipeds are powerful; palm is fusiform, lacking any protuberance or process; terminal claw is sharp, well-curved and strongly chitinized, reaches a trifle beyond the middle of palm length and carries a short hair on its swollen base. Sternal fork has an oval base and a pair of widely diverging conical branches, each of which bears at the junction with the base on the outside a far smaller, similar-shaped accessory branches. The fork is associated some distance apart on either side with a semicircular chitinous plate of sternal surface.

First pair of thoracic legs retain two-jointed rudiment of endopodite. There are behind them a pair of round tubercles, locating one on each side of midline. First two endopodite joints of second legs are dilated outward to form

a crescentic lobe. Legs of third pair have both the rami three-jointed; first joint is much reduced in the both and second joint strongly elongates in endopodite in the form of a crescentic lobe, extending inward along the margin of basal apron. Fourth pair are four-jointed; basal joint is enlarged into an oval form and longer than the rest three joints combined together. No fifth and sixth legs. Armatures on four pairs of legs are diagrammatically indicated in Table II.

Table 2. Details of the armature on the legs of *Gloiopotes hygomianus* STEENSTRUP et LÜTKEN

Leg	Border	Sternal plate	Protopodite		Exopodite			Endopodite		
			I	II	I	II	III	I	II	III
I	outer inner		1p		1h c	3H, 1q 3P		c	c 1p, 1rh, 1p	
II	outer inner	f	1s 1P	f, 1h f, 1s	f, 1H c, 1P, c	1H 1P	2H 5P, 1Q	c 1P	c c, 2P	6P
III	outer inner	f	f, 1p 2s		1H′ 1P	1rh c, 1P	3rh 5p	c	c 2P	c, 4P
IV	outer inner				3rh, C, 1H	C, 1H	C, 3H			

Of three non-plumose terminal spines on first legs, the externalmost unforked and doubly edged with finely serrated rim; the other two tripartite, their outer and inner branches colored in yellow owing to stronger chitinization and edged with a serrated rim, while the middle one thin and membraneous. External spines on exopodite of second legs with narrow rims on two opposite borders, that of first joint associated at its base with a tranverse row of short spinules. Hook at the base of exopodite of third legs curved inward, with bifid apex; outer branch shorter than the inner and the two interposing between each other an oval sinus. All the spines on fourth legs doubly edged with pectinate rim and associated at their bases with finely striated membrane with pectinate margin. Spinules bordering the terminal three joints sharp and becoming stouter, but less numerous successively from proximal joint to the distal.

Caudal rami slender, half as long as abdomen, styliform, extending straight backward and parallel with each other. They bear three unequal terminal spines, a solitary one on the outside at proximal one third of their length and tiny scattering spinules on their surface.

Male: Smaller in size and relatively narrower than female, 8.27 long from top of head to end of caudal rami; carapace 4.73×3.20, fourth thoracic segment, on the midline 0.53 long, same, including dorsal plates 1.47×2.46, genital segment 1.77×1.67, its posterior process 1.07 long, abdomen 1.20 long, first segment 0.27×

0.60, second segment 1.08×0.47, caudal ramus 1.20 long (all in mm). Coloration as in female save that the genital segment is tinged with lemon-yellow color

Fig. 6. *Gloiopotes hygomianus* STEENSTRUP et LUTKEN. A–I, female; A, second maxilliped; B, sternal fork; C, postero-lateral angle of carapace; D, fourth leg; E, terminal end of same; F, postero-lateral lobe of genital segment and abdomen, ventral view; G, spinule on the surface of carapace; H, marginal spines of genital segment; I, caudal ramus; J–L, male; J, second antenna and two maxillae; K, second maxilliped; L, postero-lateral process of genital segment and abdomen, ventral view. A, B, D, I ×37, C, F ×17, E ×110, G ×305, H ×155, J, K ×47, L ×25.

in formalin.

Carapace much narrower than in female, two thirds as wide as long, with frontal plates acuter and more prominent. Dorsal plates of fourth segment far smaller than and different in shape from the corresponding structure of female, four fifths as wide as carapace in their combined width and about twice as wide as long. They are foliaceous lamellae, acuminating toward postero-lateral angles, cover the succeeding segment only in its small parts of antero-lateral angles and are separated from each other by a broad quadrate median sinus which is flaring widely toward the rear. Genital segment is about one third as long as carapace, as long as its own width, nearly ovate, though obliquely truncate at postero-lateral corners, where it carries on each side a posteriorly directing, ensiform process which ends in narrow, outwardly turning apex and extends as far back as the middle of abdomen. The segment and the processes have no marginal row of spinules, but the latter are tipped by three short spinules. Abdomen is tubular, two-segmented, about two thirds as long as the preceding segment, and somewhat narrows caudally. First segment is one third as long as the second.

First antennae relatively better developed than in female. Apical joint of second antennae directed ventrally, turned inward so as to draw nearer to the corresponding member of the opposite side, and bifurcate at the tip; two branches unequal in size, the longer member more strongly chitinized than the other, being colored in dark brown. First maxillae bear a short inner, spiniform accessory process. Accessory branch of second maxillae missing. Palm of second maxillipeds slenderer than in female and armed with a short conical process on inner border some distance in front of the base. Claw elongates, tapering distally to terminate in a thin aciform, but well-chitinized apex which reaches the base of palm, and carries a short conical process on the upper surface near the base in addition to ordinary accessory spine.

Otherwise as in female.

Remarks. So far as I am aware, the present record belongs to the first one from the Pacific after the lapse of a century from its erection.

Genus *Brachiella* CUVIER

Brachiella thynni CUVIER

CUVIER 1817, Régne Animale, 287, Pl. 15, Fig. 5: SHIINO 1956, 283-287, Figs. 8-9. For synonymy and bibliographies refer to SHIINO 1956.

Occurrence: Nine females and six males were obtained from the external surface of *Acanthocybium solandri* (C. and V.), off Cocos Island, by W. L. KLAWE, December 3, 1959.

The largest female: Head and neck 11.3 long, arm 3.6 long, trunk 5.0×4.2×2.8, caudo-ventral process 8.8 long, caudo-dorsal process 11.2 long, egg case 15.9 long (all in mm). The female is unaccompanied by the male, but carries a species of *Alepas* attached to the egg case.

The next largest female: Head and neck 9.2 long, arm 2.8 long, trunk 5.2×3.6×2.0, caudo-ventral process 5.4 long, caudo-dorsal process 9.6 long, egg string 10.4 long. Male associated with this female: 1.92 long, head 0.88×0.56, trunk 1.04×0.72 (all in mm).

Color of females in formalin white, trunk very slightly tinged with pink, egg strings varying in color from white to dirty yellow. One of the females is mutilated from the posterior end of neck together with the arms, another has the arm of one side mutilated from the middle and again another has its trunk burst on one side.

Distribution: The Adriatic, the Mediterranean, Belgian and British coasts of the Atlantic, the Gulf of Mexico, Ceylon, eastern and western parts of the North Pacific.

Hosts: Refer to SHIINO 1956.

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Copepods Parasitic on Remoras from the Bay of Bengal

(*With four text-figures*)

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The year before last, I recorded some of the parasitic copepods found on the fishes collected by the students on board the "Taiseimaru", the trainer ship of our University, during her first cruise in 1954 to the Indian Ocean. After the publication of that report, I received further materials taken in the Bay of Bengal on the occasion of her cruise to this region in 1958. Out of them, the forms obtained from migratory fishes have already been treated in one of my papers published in the last year. Here I propose to give notes on two interesting parasites found on remoras. One is the male of a *Caligus* which can not be assigned to any of the known species decisively and the other belongs to the species originally recorded from the Atlantic coast of North America and unknown to the present region.

Genus *Caligus* MÜLLER

Caligus sp.

(Figs. 1 and 2)

Occurrence: A single male found on the outside surface of a remora taken in the Bay of Bengal, 16°36′–16°40′ N., 92°13′–92°34′ E., April, 1958.

Male: Body more convex above than usual, yellowish brown in formalin and thickly covered all over the dorsal surface with brown chromatophores of irregular shape (probably black in living state). Length 4.26, carapace 2.50×1.82, fourth thoracic segment 0.22×0.64, genital segment 0.82×0.71, first abdominal segment 0.22×0.43, second segment 0.54×0.34 (all in mm).

Carapace longer than wide, occupying more than half of the entire length, oval in outline, widely round on sides and bordered with narrow marginal flange. Frontal plates prominent, three fifths as wide as carapace, widely curved in front and with comparatively large-sized lunules near extreme lateral ends. Postero-median lobe extending some distance beyond narrow lateral lobes, gracefully curved on either side and forming a very short, narrowed waist at rear end. Sinuses narrow, ovate and open backward. Transverse dorsal rib strongly arched forward like a chevron; anterior halves of longitudinal ribs short, divergent forward, and their posterior halves also divergent, but incurvated. Eyes large, at the centre of the anterior area of carapace.

Fourth thoracic segment transversely linear, about one third as wide as carapace, same time as long as its own width, well round at the bases of the legs and fused with the succeeding segment. Genital segment one third as long as carapace, a little longer than wide, widely round on sides and truncate on hind border. From the posterior one third of its length, it narrows somewhat more rapidly to the rear than to the front. Abdomen as long as the preceding segment, but narrower, and only insensibly diminishing in width backward; sides straight, with a slight notch at anterior one third of their length, indicating the boundary between the constituent segments; caudal margin obliquely truncate at either angle to receive the base of caudal ramus.

Fig. 1. *Caligus* sp., male, dorsal view. ×17

First antennae relatively short; apical joint claviform, tipped with a number of long and short hairs; basal joint longer than the apical and fringed with rows of plumose spines as usual. Second antennae robust, first joint narrow, horizontal, with parallel striation on the surface near the end, second joint folded back over the first, to which it equals in length, and carrying an oval, striated, subterminal bulge, and third joint very short, unguiform, folded back over the second and with two triangular surface ridges as well as a short spinule of posterior side. First maxillae well-developed, consisting of long, strongly curved, hook-like blade with blunt tip and oblong base bearing two long hairs, which are associated with another hair present on sternum just behind the base. Second maxillae feebler than the first, with triangular base and blunt, finger-like apex. Exopodite rudiment consisting of a longer and two shorter hairs. Terminal joint of first maxillipeds longer than the basal, ending in two unequal claws doubly edged with pectination, and bearing a short distance behind the end a narrowly triangular accessory lamina. Second maxillipeds powerful; palm fusiform in outline and armed on the inner margin with a prominent round bulge which is grooved on the surface; claw short, only slightly curved, closing down against the groove of that bulge of palm and carrying a short subterminal spinule. Sternal fork has small shield-like base and two broad, flattened, divergent branches, which are curved inward at their blunt apices and more or less frilled on the surface.

First legs have columnar rudiment of endopodite near the end of protopodite. They are accompanied just behind them with a pair of submedian round

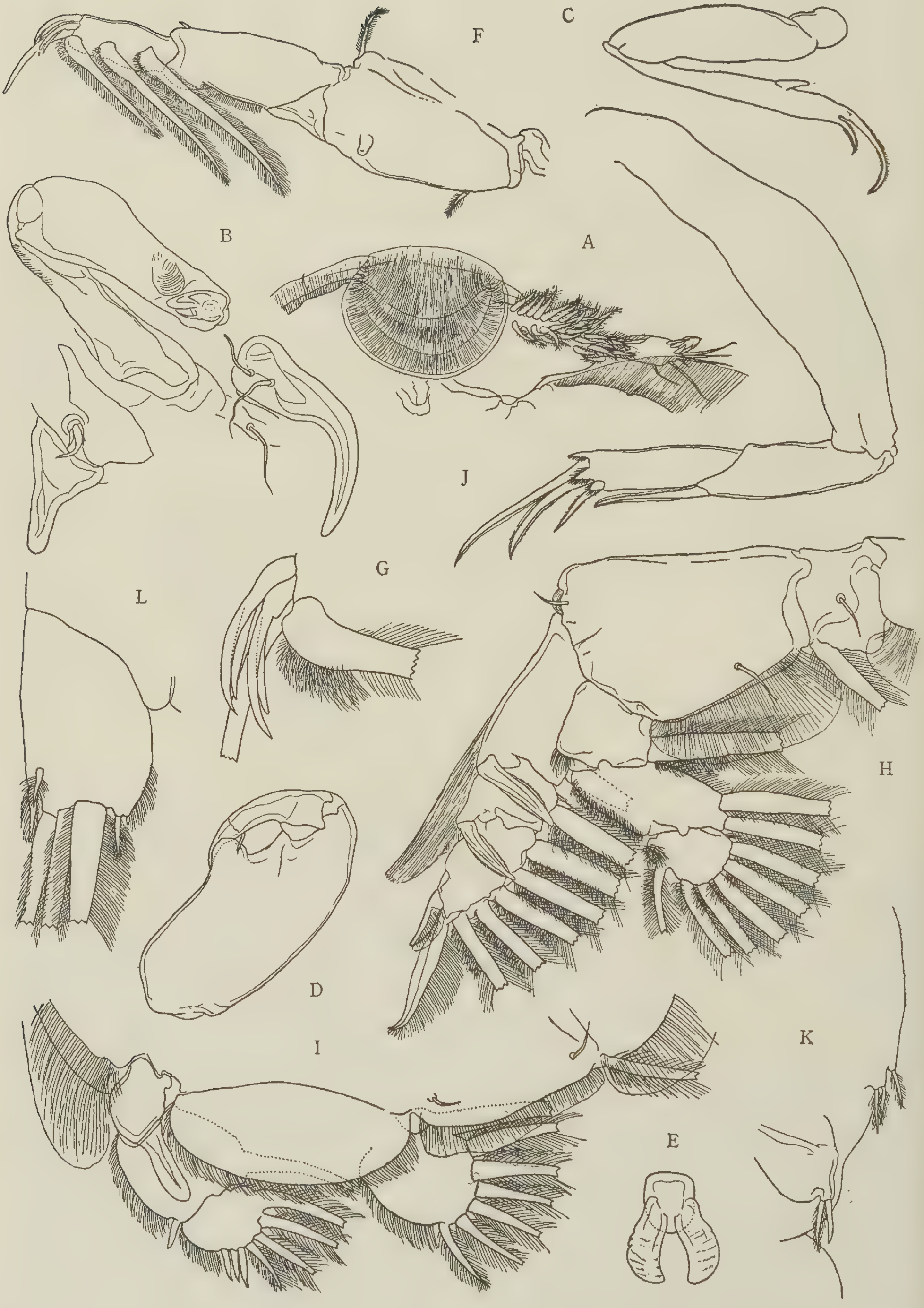

Fig. 2. *Caligus* sp., male. A, first antenna with lunule; B, second antenna and maxillae; C, first maxilliped; D, second maxilliped; E, sternal fork; F, first leg; G, tip of same; H, second leg; I, third leg; J, fourth leg; K, lateral margin of genital segment, ventral view showing fifth and sixth legs; L, caudal ramus. A, C, D ×75, B, E, F, H–L ×110, G ×305.

tubercles of sternum. Exo- and endopodite of third legs widely apart from each other owing to the intrusion of crescentic expansion of basal apron between them. Exopodite composed of two well-developed joints, while endopodite practically one-jointed, having basal joint strongly reduced. Fourth legs three-jointed; basal joint longer than the other two combined together; these latter bordered from each other by an oblique boundary. Armatures on the first four pairs of legs are diagrammatically indicated in Table I.

Table I

Details of the armature on the legs of *Caligus* sp.*

Leg	Border	Sternal plate	Protopodite		Exopodite			Endopodite		
			I	II	I	II	III	I	II	III
I	outer inner		1p 1p		1rh c	3H 3P				
II	outer inner	f	1s 1P	f, 1s 1s, f	f, 1H c, 1P	1H c, 1P	1h, 1H, 1Q 5P	c 1P	cc c, 2P	cc c, 6P
III	outer inner	f	f 1P, 2s, f		1H′, c, 1h 1P	c, 3h c, 4P		1P	c 6P	
IV	outer inner				1H	3H				

Of three apical spines on first legs, the innermost is simple, more than twice longer than others, which are subequal and deeply forked into two unequal, closely adjoining branches. Plumose spines on apical joint fringed with irregularly grown hairs in the basal region of outer border for a short distance, but with regular uniserial hairs in the rest region and on the other border. Plumose spines on the exopodite of second legs and some of them on the endopodite similar in structure to those of first legs. External spines on the first two exopodite joints doubly edged with finely pectinate, crescentic rim; second external spine on third joint with a broader, striated membrane. Basal claw on the exopodite of third legs has swollen base and internally directed, straight apex, which is blunt and flattened. Spines on fourth legs either pectinated or with narrow rim on two opposite borders. Those on third joint of the legs graded in length from inside to outside, the innermost attaining thrice the length of the outermost; all of them accompanied at the base with a triangular, pectinated

* Abbreviations used in Tables:

c, row of hairs; f, membraneous flange; H, longer simple spine; h, shorter simple spine; H′, hook-like spine; P, longer plumose spine; p, shorter plumose spine; pc, pectination; Q, spine hairy on one side, edged with membrane on the other side; rh, rudimentary spinule; s, solitary hair. Roman numerals indicate the numerical orders of legs or their joints and arabian numerals represent the number of spines, hairs or others present on them.

basal lamina. Spine on second joint as long as the middle spine of apical joint, but lacking basal lamina.

Fifth legs represented by two short plumose spines arising from a low tubercle present on the ventral surface of genital segment in its widest region on extreme lateral margin and by another similar spine placed just in front of them. Sixth legs are triangular bulges of ventral surface of the same segment at its posterior end and tipped by a simple and a plumose spines.

Caudal rami projecting straight backward, quadrate in shape, terminating in three elongate plumose spines, which are associated on the outside with two very short plumose spines and on the inside with another similar one, and the inner border fringed in its distal half with a row of short hairs.

Remarks: In the configuration of the posterior body segments, the present male is nearly allied to *C. rufimaculatus* WILSON, *minimus* OTTO and *bombayensis* RANGNEKAR. It differs from the first of these in the lack of the spine about the middle of the outer border of the terminal joint of the fourth legs, from the second in the structure of the second maxillipeds and from the third in the fourth legs consisting of three joints instead of four. In so far as the female is unknown, the present male can not be assigned to any of the species of *Caligus* in which the male form is known.

Genus *Lepeophtheirus* NORDMANN

Lepeophtheirus crassus (WILSON et BERE)

(Figs. 3 and 4)

Gloiopotes crassus, BERE 1936. Amer. Midl. Nat., **17**: 590-593, Pl. 5, Figs. 104-111, Pl. 6, Figs. 125-155.

Occurrence: Twenty-one adult females, five adult males, one juvenile female and three juvenile males taken on the body surface of *Echeneis albescens* T. and S. in the Bay of Bengal at a point 16°40′ N., 92°13′ E., April 20, 1958.

Female: 6.00×3.04 in the largest female, 4.56×2.64 in the smallest one. Measurements in the figured female: total length 5.90, carapace 3.39×3.22, fourth thoracic segment 0.39×1.44, genital segment, on the midline 1.39 long, same on the lateral region 1.83 long, 1.89 wide, first abdominal segment 0.39×0.44, second segment 0.42×0.50, egg strings 3.61 long (all in mm). Body pellucid in formalin, whitish, no black pigment; eyes brownish, egg strings pale yellowish.

Carapace orbicular, about as wide as long. Frontal plates three fifths as wide as carapace, widely round on margin except for a slight median incision, and not prominent. Two sides gracefully curved, fringed with a row of short hairs besides with relatively narrow membranes. Postero-median lobe half as wide as carapace, with margin widely round and only slightly exceeding lateral lobes. Sinuses shallow, narrow and open backward. Transverse dorsal rib

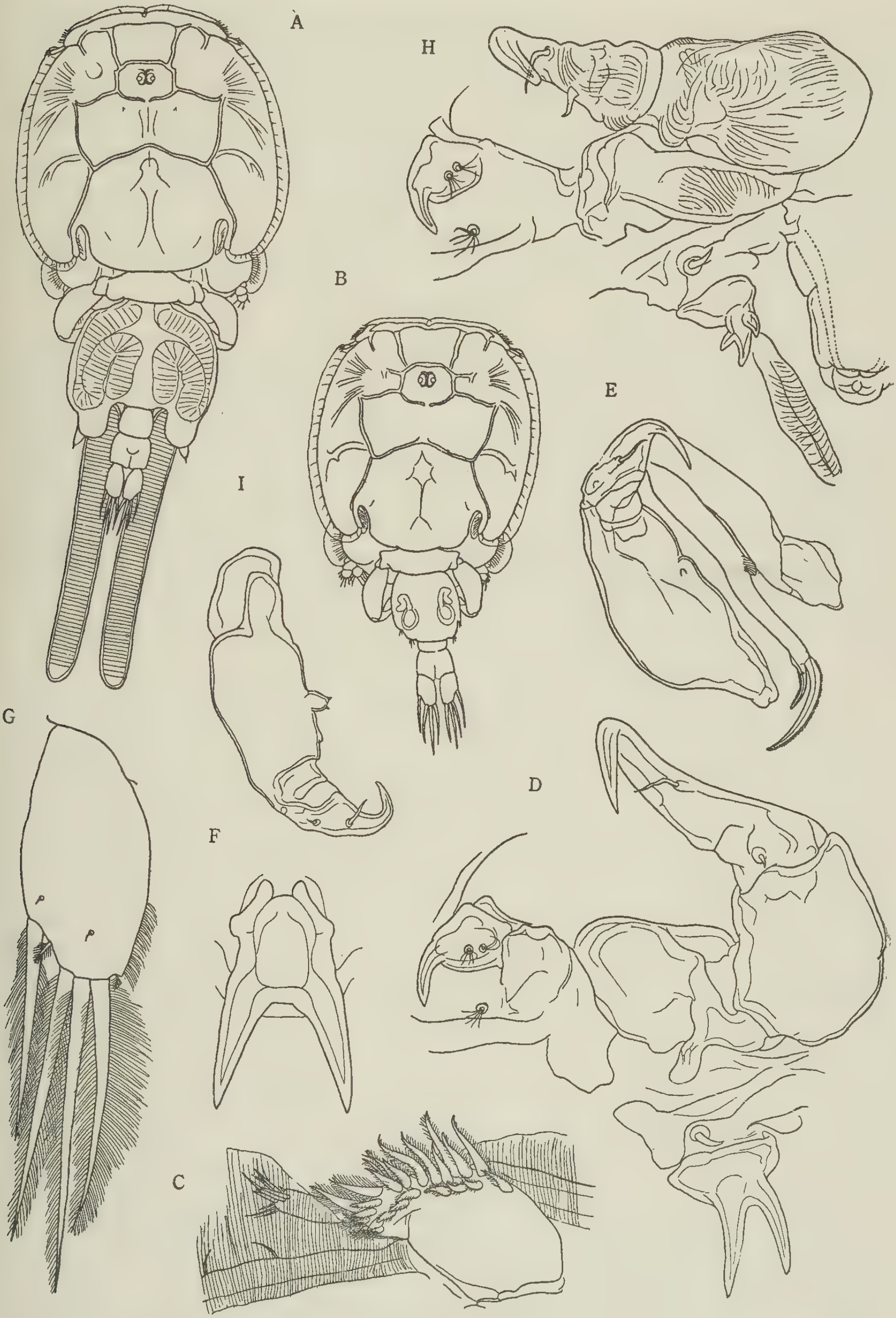

Fig. 3. *Lepeophtheirus crassus* (WILSON et BERE). A, female, dorsal view; B, male, dorsal view; C–G, female; C, first antenna; D, second antenna and two maxillae; E, first and second maxillipeds; F, sternal fork; G, caudal ramus, ventral view; H–I, male; H, second antenna and two maxillae; I, second maxilliped. A, B ×10.8, C, D, F–H ×75, E ×50, I ×45.

traversing the carapace through its centre and arched forward. Longitudinal ribs diverge from each other both forward and backward and join at the fore end on either side an internally running short horizontal rib which reaches each postero-lateral angle of median quadrilateral frame circumcribing the peri-ocular region. The frame is connected at each antero-lateral angle with a suture descending from the frontal plate, but is interrupted on posterior side on the median and encloses relatively large eyes at its centre.

Fourth thoracic segment short and narrow, less than half as wide as carapace, transversely linear; dorsal plates very poorly developed, hardly or, at times, only slightly covering the succeeding segment; lateral sides obliquely truncate. Genital segment about three fifths as wide as carapace, one and third times as wide as its own length on the midline, with gracefully curved shoulders, and produced in the rear on either side into a pair of oval lobes which reach beyond first abdominal segment. The lobes are separated from the sides of abdomen for some distance and their lateral margins are somewhat reentrant from the general outline of genital segment. Abdomen about three fifths as long as the preceding segment, half as wide as its own length, two-segmented; anterior segment only slightly narrower than the posterior, but equaling in length. Caudal end almost truncate.

First antennae as usual; apical joint slender, relatively short, tipped with several bristles, and basal joint fringed with double row of plumose spines along fore margin; spines of outer row rather stouter and much longer than those of inner row. Second antennae robust, three-jointed; first joint horizontal, with a blunt, flattened posterior spine, second joint columnar, longitudinal, and third joint directing outward to form a strongly curved, stout hook with sharply pointed apex; the last joint furnished with a tiny hair at the base and with a longer hair about the middle of its length. First maxillae have short, slightly curved, sharply pointed blade; their base as long as blade, pentagonal in shape and bearing on the surface two tubercles surmounted by a few short hairs. A similar ciliated tubercle present on the sternum just behind the maxillary base. Second maxillae stouter than the first, having short but wide, crescentic base which issues two long, sharp, diverging branches; exopodite rudiment consisting of a single hair. First maxillipeds geniculated; apical joint slender, tipped by two unequal claws with finely pectinate rim, and carrying a crescentic accessory lamina about the middle of its length. Second maxillipeds powerful; palm fusiform, with a low tubercle at the centre; claw not attaining to the base of palm, but strongly curved, stout, sharply pointed and carrying a short spinule near proximal end. Two arms of sternal fork directing straight backward, acuminating toward sharp point, and a little divergent from each other inserting a V-shaped sinus.

Endopodite of first legs very rudimentary, thumb-like in form and armed neither with spine nor with hair. Sternum just behind this pair of legs shows a pair of round tubercles surmounted by a tiny spinule. Two rami of third pair close to each other; endopodite two-jointed, with basal joint dilated outward into a crescentic lobe; exopodite three-jointed, but with basal joint rudimentary. Fourth pair robust, four-jointed; first joint showing a slight curvature, rest joints somewhat slender, straight and bordered from one another by oblique boundaries. Armatures on the four pairs of legs are indicated in Table II.

Table II

Details of the armature on the legs of *Lepeophtheirus crassus* (WILSON et BERE)

Leg	Border	Sternal plate	Protopodite		Exopodite			Endopodite		
			I	II	I	II	III	I	II	III
I	outer inner		1p		1rh c	3H, 1P 3P				
II	outer inner	f	2s 1P	1s, f f, 1s	f, 1H c, 1P	1H c, 1P	2H, 1Q c, 5P	c 1P	c c, 2P	c c, 6P
III	outer inner	f	f 1P, f, 2s		1H′ 1P	c, 1h c, 1P	c, 3h c, 4P	c 1P	c c, 6P	
IV	outer inner		3s		1rh	pc, 1H	pc, 3H			

Of apical non-plumose spines on first legs, the outermost simple, while the others bifid; all of them sharply pointed, pectinated on the sides and accompanied at their bases each with a small oval lamina. External spines on first two exopodite joints of second legs and first spine on third joint finely pectinate on their sides; the spine on first joint with a transverse row of short bristles at its base. Second spine on the last joint doubly edged with broad membrane and third spine with a broader membrane on one side, ciliated on the other side. Basal hook on the exopodite of third legs curved at right angles; its basal portion with two tiny hairs on outer border and apical portion relatively long, sharply pointed and with a narrow external rim. Terminal spines on fourth joint of fourth legs graded in their lengths, the innermost more than thrice longer than the outermost, which is a little shorter than the middle member. Spine of third joint as long as the outermost spine of the last joint. All of them doubly edged with pectination or pectinate rim except the innermost one of the last joint which is entire on inner edge, and all provided with pectinate basal lamina. Spine on second joint rudimentary and yet provided with basal lamina. Sixth legs are styliform appendices of the ventral surface of genital segment issued from the immediate neighborhood of the bases of posterior lobes. They extend diagonally backward, attaining beyond the end of

Fig. 4. *Lepeophtheirus crassus* (WILSON et BERE). A–F, female; A, first leg; B, tip of same; C, second leg; D, third leg; E, fourth leg; F, postero-lateral lobe of genital segment showing sixth leg rudiment, ventral view; G, male, postero-lateral part of genital segment showing fifth and sixth leg rudiments. A, C–G ×75, B ×155.

posterior lobes, and are armed with three short plumose spines along their outer margin as well as with a number of tiny spinules on their surface. Each of fifth legs may be a short plumose spine present just outside the base of sixth leg.

Caudal rami ovate, terminating in four plumose spines; the outermost of these apart from the others which are crowded. The rami bear an additional tiny plumose spinule at inner distal angle, another between the two outer terminal spines, a row of short hairs fringing terminal half of inner border and two tiny spinules on under surface.

Male: Coloration as in female. Length 4.66, carapace 3.00×2.72, fourth thoracic segment 0.33×1.00, genital segment 0.89×0.89, first abdominal segment 0.17×0.39, second segment 0.33×0.47 (all in mm).

Carapace same in structure as that of female. Fourth thoracic segment with dorsal plates scarcely discernible. Genital segment one third as long as carapace, as wide as its own length, barrel-shaped, sides widely round, but their posterior one third somewhat reentrant. Abdomen about three fifths as long as the previous segment, a little longer than wide, two-segmented. First segment very short, half as long as the second.

First antennae and sternal fork show no sexual difference from those of other sex. Second antennae have irregular bulges or swellings on the terminal part of second joint and on the basal part of third in addition to series of parallel surface ridges of each joint. First maxillae have the blade shorter than in female and somewhat more strongly curved. Second maxillae feebler than in this sex; their base issuing a short conical blade which carries two shorter secondary branches, one on each side. Sternum in the region just behind second maxillae shows a pair of diagonal ridges with corrugated surface. Palm of second maxillipeds resembles that of female, but is armed on inner surface with a papilliform protuberance which carries two tiny spinules; claw has two unequal hairs. Fifth legs are short narrow lobes present on the genital segment on the outer margin and visible from above as a short process of sides. They are directed backward, tipped by three short plumose hairs and carry another hair on outer border. Sixth legs are represented by a pair of broad, triangular elevations of the ventral surface of the segment, locating on either side of the fore end of abdomen, and bear three apical plumose spines.

Otherwise as in female.

Remarks: This species originally assigned to the genus *Gloiopotes* strongly differs from the other species of the genus in the structures of body segments and of appendages. The caudal rami which are lamellar instead of styliform, the endopodite of the first legs which are unjointed and not distinctly jointed as in *Gloiopotes*, and the two-jointed endopodite of the third legs, which

are three-jointed in this genus and have the second joint dilated so as to be closely applied to the margin of basal apron, all tell the far remote affinity of the species to this genus. The most distinctive character, on account of which the species has been placed in *Gloiopotes*, consists in the presence of dorsal plates on the fourth thoracic segment. These plates, however, are so strongly reduced that they scarcely deserve this name. Excepting this point, the species possesses every characteristic of *Lepeophtheirus*. In my opinion, therefore, it seems to be better to transfer this species from *Gloiopotes* to *Lepeophtheirus*.

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On the Form and Size of the Swimbladder of Goldfish (*Carassius auratus* L.) in Special Reference to its Body Equilibrium

(*With Plates XVIII-XXII*)

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Preface

It is a well-known fact that the goldfish (*Carassius auratus* L.) has two lobes of swimbladder and its posterior one communicates with the digestive tube by the pneumatic duct since the fish belongs to *Ostariophysii*.

Franser-Brunner (1931) reported that the proportion of the two lobes is correlating with the size of caudal fin in the fish, and that no doubt the phenomenon is due merely to the adjustment of the altered center of gravity.

Terao and his co-workers (1956) showed that the correlation of the two lobes varies in accordance with artificial unbalance of the fish body. While, last winter the present writer happened to see some goldfish fioating upside-dowon or inclined laterally under the surface of the farm water. By this chance,

he observed the swimbladders of normal and abnormal fish by means of photographs of X-ray and found that the relative size of the two lobes is different in each individual of fantail variety, "*Ryukin*" in Japanese. Such an abnormal phenomenon is said to have been observed sometime in the other short body varieties of gold-fish, i.e. *Rantyū*, *Sisigasira*, etc. in the other farm.

It is supposed that such an abnormal condition of the fish may be caused by some disease of fish, and the writer is now researching why the form and size of the bladder are changed so much.

In the following, the result on the X-ray research of their swimbladders will be explained.

Method of Experiments and Material Employed

"Softex" X-ray apparatus was used to observe the form and size of the swimbladder of goldfish. For comparing the normal with the abnormal bladder, the writer set up two straight lines on the photographs, the one from the point of the anterior to the posterior end of the vertebral column, and the other is a line of long axis of the bladder.

The angle of the two lines was named a "bladder angle", and the conditions of the bladder were discussed, judging from the different angles of every fish.

As the definition of the straight line of the bladder axis can not strictly be set up, the meaning of the bladder angle is not so exact, but the writer believes that the difference of the position of bladders may be compared, though to some extent.

To compare with the bladders of other varieties of the goldfish, he used not only a fantail variety named *Ryukin*, but sometimes employed *Wakin* and comet-variety named *Sibunkin*.

Anatomy of them was also done. As the size and location of the bladder is considerably changed, he let the fish into the salt water to see how the bladder size changes artificially.

He sucked up the gases in the bladders by the vacuum pump and observed them turning to normal condition.

He further observed the change of the body by the effect of destructing the caudal neurosecretory system with a heated needle, in accordance with ENAMI's opinion (1956).

Experiment

I. Observations

1. Observation of the swimbladder

Normal condition: On February 27th, 1960, the eight normal goldfish

(*Ryukin*) were collected in the farm and their photographs were taken. The results are shown in Table 1 and Plate XVIII, Fig. 1. At that time the water temperature of the farm was 3°C., the fish were swimming slowly in the water.

Table 1. Showing the angles of the swimbladders of normal *Ryukin*.

	Bladder angle (degree)	Size of lobe		Remarks
		Anterior lobe	Posterior lobe	
1. A	28.0	One	—	
B	17.5	One	—	
C	15.0	L	S	Normal
D	19.0	L	S	,,
E	16.6	L	S	,,
F	22.7	L	S	Inclined lateral
G	13.6	L	S	Normal
H	12.3	L	S	Inclined lateral
Average	18.0			

L...Large. S...Small.

In this table, the average bladder angle was 18.0°, and the two of them (Fig. 1, A, D) only had one bladder while the other six had two lobes (Plate XVIII. Fig. 1, A-H). The anterior lobes were always larger than the posterior ones, but the posterior lobes in two in the six are inclined to the lateral as will be shown in Fig. 1 F, H.

Abnormal condition: At the same time he took the photographs of the eight abnormal fish, which were swimming rather vigorously upside-down under the surface of the water and they lived about three months in this condition and the figures of their bladders are shown in Table 2 as follows and Plate XIII, Fig. 2.

Table 2. Showing the angles of the swimbladders of abnormal *Ryukin*.

	Bladder angle (degree)	Size of lobe		Remarks
		Anterior lobe	Posterior lobe	
2. A	34.2	One	—	
B	35.2	S	L	Very rare
C	22.6	L	S	
D	32.5	One	—	
E	21.0	L	S	
F	26.9	L	S	
G	27.6	One	—	
H	26.6	L	S	
Average	28.3			

The average angle of these abnormal fish was 28.3° and inclined 10.3°

downward in comparing with that of the normal bladder. This is the reason way the fish had to be in the upside-down condition by the hydrostatical equiliblium. Moreover, three in the eight (Fig. 2, A, D, G) seemed to be only one lobe and the anterior lobe of a fish (Fig. 2, B) was smaller than posterior one. This strange form of the bladder is supposed to be a peculiar case.

The writer also took photographs of the lateral inclined eleven fish, and the angles of them are shown in Table 3 and Plate XIX, Fig. 3, A–K.

Table 3. Showing the angles of the swimbladders of lateral-inclined *Ryukin*.

	Bladder angle (degree)	Size of lobe		Remarks
		Anterior lobe	Posterior lobe	
3. A	35.2	L	S	Posterior lobe, irregular.
B	52.6	L	S	
C	42.2	L	S	Inclined lateral
D	44.0	One	—	
E	46.8	One	—	
F	45.2	One	—	
G	38.2	One	—	
H	31.5	One	—	
I	33.5	One	—	
J	33.0	One	—	
K	35.8	One	—	
Average	39.8°			

The average angle of the bladders was 39.8°, and was 11.5° larger than that of upside-down fish. However, both of them were abnormal, and their angles were uniformly larger than that of normal fish (Plate XIX, Fig. 3, A–K).

In these eleven fish, three fish had two lobes (Fig. 3, A, B, C) and the posterior lobes of A was somewhat large in addition to the deformation, and that of C was remarkably inclined lateral. The other eight fish had only one bladder respectively.

The writer observed that some of the abnormal fish which had lived since last winter became normal when the water temperature increased gradually high with the arrival of the spring. In the following Table 4, and Plate XIX, Fig. 4, A–F, he will show their figures.

The average angle was 26.7° and it is strange that all the bladders of the fish in this table should have no posterior lobe, but have only one as shown in Fig. 4.

From these four tables described above, we can find that the normal condition of the fish is caused by the smaller angle such as from 18.0° to 26.7°,

Table 4. Showing the bladder angles of the newly recovered fish which have been in abnormal condition.

		Bladder angle (degree)	Size of lobe		Remarks
			Anterior lobe	Posterior lobe	
4.	A	11.0	One	—	No posterion lobes were observed
	B	9.5	One	—	〃
	C	8.9	One	—	〃
	D	18.1	One	—	〃
	E	28.9	One	—	〃
	F	25.5	One	—	〃
Average		26.7°			

while angles in the abnormal condition are larger than those data, as are observed 28.3° in Table 2 and 39.8° in Table 3.

2. Structure of the body cavity

It is said that the abnormal condition is only observed in the goldfish of short body, such as *Ryukin* (the body is short, somewhat high, all fins are long), *Rantyū* (the body is short, broad roundish, no dorsal fin, the other fins are short, excrescent head), and *Sisigasira*, lion head, (a direct variety of *Rantyū*, but all fins are long, body also short and excrescent head) etc., and never observed in the other varieties of the fish which have slender bodies.

When the body cavity of those short body fish is opened, we shall see a cavity large in width, tall in height but the length is rather short.

Then, the swimbladder must be inclined downward posteriorly (Plate XX, Fig. 6, A), while those of *Wakin* (slender body and all fins are short) and *Sibunkin* (slender body and the caudal fin is specially long), both of them are the variety of goldfish, are situated almost horizontally as shown in Plate XX, Fig 6, B and C.

Of the two lobes of swimbladder of *Ryukin*, the anterior lobe is covered with connective tissue layer though the posterior one is naked, and the bladder is situated freely in the cavity, except the anterio-superior part of the anterior lobe is connected with the body wall.

For this reason, the position of the posterior lobe in these short body fish is apt to incline lateral or downward as shown in Plate XVIII, Fig. 1, F, H, Plate XIX, Fig. 3, C and Plate XX, Fig. 6, A, Fig. 7, A and Fig. 8, A, C.

We shall never see an inclined bladder in the slender body goldfish such as *Wakin* (Plate XX, Fig. 6, B, Fig. 7, B, C) and *Sibunkin* (Fig. 6, C), and also in a silver carp (*Carassius auratus*) or even normal carps (*Cyprinus carpio*), because, the body cavity of those fish is too narrow to incline due to their slender body.

3. Size of the swimbladder

From the results of his observation of the size of the bladder since last December to this November, the writer has found the existence of many kind of sizes of the two lobes as mentioned above; sometimes the anterior lobe is large and posterior one is small, which in other times its reverse figures (Plate XVIII, Fig. 2, B) are observed and even in many cases only one bladder appeared as will be shown in Plate XVIII, XIX, XX. He also saw the size of the posterior lobe sometimes is irregular (Plate XIX, Fig. 3, A) and apt to incline lateral as shown above.

These several facts described here show us it is natural that the abnormal condition should have appeared frequently in the short body goldfish such as *Ryukin*, *Rantyū* or *Sisigasira*, but never appear in the slender body fish.

However, he could not understand why the size of the lobes differs sometimes even in the case of anterior lobe which is larger than the posterior one. The size of the latter is sometimes considerably large or irregular, and other times it becomes too small as is shown in the three plates. He often saw that the size of the anterior lobe was smaller than that of posterior one as mentioned above.

According to the review by JONES and MARSHALL(1953), the sea-horse is capable of changing relative volume of anterior and posterior lobes quickly and easily. The present writer has not observed the swimbladder of that fish, but he supposes that the form of the bladder of *Ryukin* may not change so quickly and easily in comparing with that of the sea-horse.

The newly recovered fish that was once upside-down or lateral had only one bladder as is shown in Plate XIX, Fig. 4, A–F; however it is supposed that such a case did not always appear and it is still questionable why the bladder of those fish is one. Because, two lobes appear in the newly recovered fish (Plate XX, Fig. 5) which has been in upside-down state and ejected gases in the bladder by the vacuum as will be described later.

II. Results of experiments

1. Effect of water temperature

It was in the winter season that the writer first found not so small number of upside-down or inclined lateral fish were in the farm, and the water temperature at that time was 3°–7°C.

The fish were floating under the surface of the water in abnormal condition and might have been suffering from the trouble; however the disease was not fatal. If they were under good condition, they might have lived for a long time as stated by VAN DUIJN (1956).

The writer experienced frequently that when the water temperature in the aquarium was elevated to about 12°C. even in the winter season, some of those

abnormal fish were recovered to be normal, and such a phenomenon was also observed in the spring season as described above.

If he gave the floating food such as small grains of bread etc. on the surface of the water, the fish which were only swimming in abnormal condition got and ate them. Finally they recovered their health gradually and became normal (Plate XX, Fig. 5). Otherwise, they always became starved to die since they were unable to eat the food on the bottom. Even in the summer season, some of them became abnormal when the water temperature in the aquarium rose as high as 27°–30°C.

Such a phenomenon could never be observed in spring or in autumn. These several facts show us that one of the causes of the abnormal condition of the fish came from their losing equilibrium ability of the body by the effect of the weakness of their health in too low or too high water temperatures or in some disease in addition to the abnormal position of the swimbladder.

2. Effect of the high concentrated salt water upon the size of the swimbladder

The present writer prepared the 0.5% and 1.0% salt waters in which he suddenly put the goldfish respectively.

In the first place, the fish in 0.5% solution seemed to be somewhat in trouble for sometime, but they soon got quiet, swimming normally in the water.

When the two normal fish (Plate XX. Fig. 8, A, B) were put into 1.0% solution, they were in distress very much and were impatient to reach the bottom of the aquarium, but their efforts were observed to be of no effect for a long process of time. But when they were transferred into the fresh water from the salt water, for instance after one hour and a half in the 1% salt solution, they immediately sank to the bottom of the aquarium (Plate XX, Fig. 8, C, D) and gradually recovered their normal state again.

When we compared the size of their bladders before and after their immersing into the 1.0% NaCl solution, we could hardly distinguish the change of them as will be seen in Fig. 8, A, B, and C, D.

From this reason, the writer thought that the phenomena of rising and sinking of fish in the water seem to be caused by the very small change of size of their bladders in the water. Probably the difference of sizes was too small to judge the decrement of them as shown above. It is supposed that some influences of the osmotic pressure might have contributed to this occasion, but such effects might have been small, if there were any.

3. On the ejection of gases in the swimbladder by means of a vacuum pump

When the air over the water in which goldfish swim was sucked out by a vacuum pump, the fish blew out small bubbles of their mouths and sank to the bottom immediately. Fig. 5, shows one example of a recovering bladder from the abnormal to the normal condition after two months (from Jan. 15 to March

19) by the effect of a vacuum. Plate XXI, Fig. 9, A, B, C, and D show the figures of the normal swimbladders, and Fig. 10, A, B, C and D show the depressed sizes of their bladders in which the air was sucked out by a pump.

After taking these photographs, he put the two fish (Fig. 10, A, and B) of them into the normal aquarium and put the other two (Fig. 10, C and D) into the other aquarium of the same size, but a thin nylon net was set horizontally three centimeters under the water surface, thus preventing the fish from absorbing the air from the surface. For the purpose of purifying the water from their excretory produts, almost the same amount of water weeds were put in the water respectively.

It was not very long before three of the four (Fig. 10, A, B and C) were recovered to be vigorous, and sometimes they tried to swim up to the water surface to absorb the air eagerly but unsteadily, but soon had to sink to the bottom by want of their ability.

After two days, the swimbladders of Fig. 10, A and B were filled with gases normally (Fig. 11, A and B) and began to swim freely in the water. The one of Fig. 10, C in the aquarium with a net became normal as shown in the figure (Fig. 11, C) in spite of its not absorbing the air from the water surface by the disturbance of the net. This fact suggests that the fish absorbed the free oxygen produced by the carbon assimilation of the weeds.

The bladder of the last one (Fig. 11, D) did not recover, but it was not in a fatal condition as will be seen in the figure, because it could not swim upward to absorb oxygen by receiving too much damage by a vacuum.

In the other experiment on November 1st, when the water weeds were not put in the aquarium, the fish could never collect gas into the swimbladder. They remained in the bottom until now (February 1st of next year) in the form of decrement size or in the state of no air in the bladder as ever. The writer could not find the sign of the excretion of gases into the bladder from other places, for instance, the blood vessels.

When we compare the forms of the swimbladder before and after ejecting the air in the bladder as shown in Figs. 9, 10 and 11, we are inclined to think that the forms of the most lobes are recovered to be just the same size as the original ones. For instance you will see a good example in Fig. 9, A, B, C and Fig. 11, A, B and C. The bladder which has a large posterior lobe became again to be of the same form (Fig. 9, A, C and Fig. 11, A and C) and the small posterior lobe got to be of the small size also (Fig. 9, B and Fig. 11, B), although all of them were once ejected gases in the bladder uniformly as shown in Fig. 10, A, B, C and D.

4. Effect of exclusion of the caudal neurosecretory system upon goldfish

ENAMI (1955, 1956, 1958) reported that some of the fresh water and estuarine

fishes such as silver carp, goldfish (*Carassius auratus*), *medaka* (*Oryzias latipes*), loach (*Misgurnus anguillicaudatus*), eel (*Anguilla japonica*) etc., have a caudal neurosecretory system near the extreme end of the vertebral column, and the system was related to the osmoregulation and swimbladder of the fish (1956). In complying with his opinion, the present writer broke and totally excluded the system of the goldfish by the heated needle. (Plate XXII, Fig. 12)

After two days, all the caudal fins of the operated fish fell out (Fig. 13), but they were somewhat vigorously swimming in the aquarium for the following three days (Fig. 14).

Fig. 15, A is a photograph taken on October 19th. The fish had been operated in the same way on October 17th two days before. B is a photograph taken on October 27th, and C is one on November 10th. In this case the dark pigments began to appear about two weeks afterwards on the posterior part of the body, and the color gradually increased and proceeded to the anterior. At last almost all the body became somewhat dark except around the head on November 10th, and it was alive until November 12th in the aquarium. The size of the swimbladders decreased step by step as will be seen in comparing with Figs. 12–15; especially the posterior lobes became remarkably smaller. However, the writer wishes to do further research on this experiment since he admits that some problems still remain to be dissolved.

Discussion

After demonstrating many thousands of goldfish, Franser-Brunner (1931) reported that all the fish he examined contained always two lobes of swimbladder and the size of the proportion of the anterior and posterior lobes were correlated with the size of the caudal fin. And he concluded that the fish which have large caudal fins such as comet or veiltail varieties has small anterior lobe and large posterior one. He was convinced that the phenomenon is due merely to the hydrostat to the altered center of the gravity, and made no description of the inclined state of the bladder.

Chapman (1948) also stated in his book that the relative size of the front and rear chambers of the swimbladder of the normal species and veiltail goldfish are quite different, and that there seems to be direct relation between the size of the hind chamber and the size of the tail.

The present writer did not treat the fish which has so large caudal fin as Franser-Brunner had handled, but *Ryukin* is a variety of rather large caudal fin.

In his research as shown in all the figures of the plates, the number of the lobe of the bladder was not always two, but also seemed sometimes one. The form and size were different in each individual even in the normal conditioned fish, and sometimes they were inclined downward or lateral in the body

cavity. Then he became to recognize at least the fact that the lobes of the swimbladder of *Ryukin* were not always correlated with the altered center of the body gravity unlike the opinions as reported by FRANSER-BRUNNER and CHAPMAN.

Without carrying out any efforts, the fish such as goldfish, carp etc., would be originally in lateral condition as you will see when they are on the brink of death or dead except some fish. However, the cause of the always normal swimming condition is supposed to be effected by habitual and unconscious efforts of the fish as well as a man standing involuntarily.

When the size and position of swimbladder were compared with *Ryukin, Wakin* and *Sibunkin* (Plate XX, Fig. 6, A, B, C), we will clearly find that the bladder angle of them is much different respectively and the body cavity of *Ryukin* is much larger and shorter than others.

Then, the conclusion will naturally come out that the bladder is apt to incline downward when the gonad or fat body increases abnormally. Therefore, this will make the fish take the upside-down state easily. Moreover, such fish were observed frequently not only in the winter but also in the summer as mentioned above. They were suffering from the extreme water temperature, 3°–7°C. in the winter season and 27°–29°C. in the mid-summer, by making their health weaker and losing the equilibrium ability by some diseases.

In his book, VAN DUIJN (1956) said that the abnormal condition of the fish was supposed to be caused by the diseases, namely, constipation or fatty degeneration of the tissues.

Thus, the writer experienced that those abnormal fish were frequently recovered to be normal by strengthing their health with nutrition and by transferring them into the suitable water, and VAN DUIJN (1956) also stated that the trouble is best prevented by giving them an abundance of varied diet.

TERAO *et al.* (1956) stated in their paper that the size of lobes of the bladder was changed by hanging a weight or a float on the fish head or on the tail. The present study shows that the change of the sizes occurred in *Ryukin* by some other factors as mentioned above.

The swimbladder sometimes, as shown in Fig. 4 and Fig. 8, B, looks to be only one, though it looks to be two in most cases. But, the writer supposes that the lobe must always exist even if it may not be observed in the photograph because of its too small size since the pneumatic duct is connected with the posterior lobe.

In two lobes, the relation of size between them is different in each individual as shown in the figures. Therefore, he has not yet clarified the problems why and how the size and form of the lobes are so varied and irregular. To this problem JONES and MARSHALL (1953) did not refer in their review of the

swimbladder. In this connection further research should be necessary.

The enigma to the writer is what is and what is not the normal type of swimbladder in *Ryukin*. In spite of his constant investigations in this matter throughout the four seasons, he has not yet reached a definite conclusion.

From the effect of high concentrated salt water upon the size of the swimbladder, he observed that the variation of the size takes place delicately, and that several hours or more were required to regulate the size.

In cases the gases are ejected artificially, the deformated bladders were recovered to the normal size within a few days by swallowing air on the water surface, if the gases in the bladder were not sucked out too much.

On the swallowing air, Evans and Dumant (1929), Jacobs (1934) also reported in their papers that physostomes replace the lost gas through the pneumatic duct by swallowing air on the surface. Evans and Dumant, moreover, considered the phenomenon may take place by pumping the air with the duct, but the present writer has a question on this matter. If the gases were totally ejected, the fish could not absorb air again even if it is near the water surface. On those conditions, Scholander *et al.* (1956) stated that the gases in the swimbladder of cod were secreted in high pressure from the blood but such a phenomenon was never observed in this fish which has no *rete*-gland. Such empty bladder fish lived for two months or more in the lateral state, sometimes swimming normally if they are given food adequately.

On the effect of exclusion of the caudal neurosecretory system, the present writer could not observe any special change except the appearance of dark pigments around the body. Here still remain some problems.

Summary

1. The writer studied on the deformation of the form and size of the swimbladder of goldfish (*Carassius auratus*) in special reference to its body equilibrium.
2. He employed mainly a variety of goldfish named *Ryukin* as materials, for the fish frequently show upside-down or inclined lateral state.
3. The occurrence of such abnormal condition was found to be caused by their inclining swimbladders downward or lateral in the short body fish and caused by their losing the equilibrium ability which came from their weak body in the extreme water temperature or which came from their suffering some disease.
4. The abnormal condition in the fish is able to be altered to the normal one by changing the water temperature and giving them nutrition to some extent.
5. The size of the two lobes of the bladder is not always correlated to the body gravity of the fish, but they seemed sometimes irregular.

6. In the waters of varied specific gravities, the fish regulate the size of the bladders delicately so as to balance their body equilibrium, but its motion is not so quick.
7. To recover their faded bladders, they swallow air on the water surface, but they could not suck it if the gases in bladders were ejected too much.
8. The effect of exclusion of the caudal neurosecretory system was not clearly known. Further experiments are necessaay.

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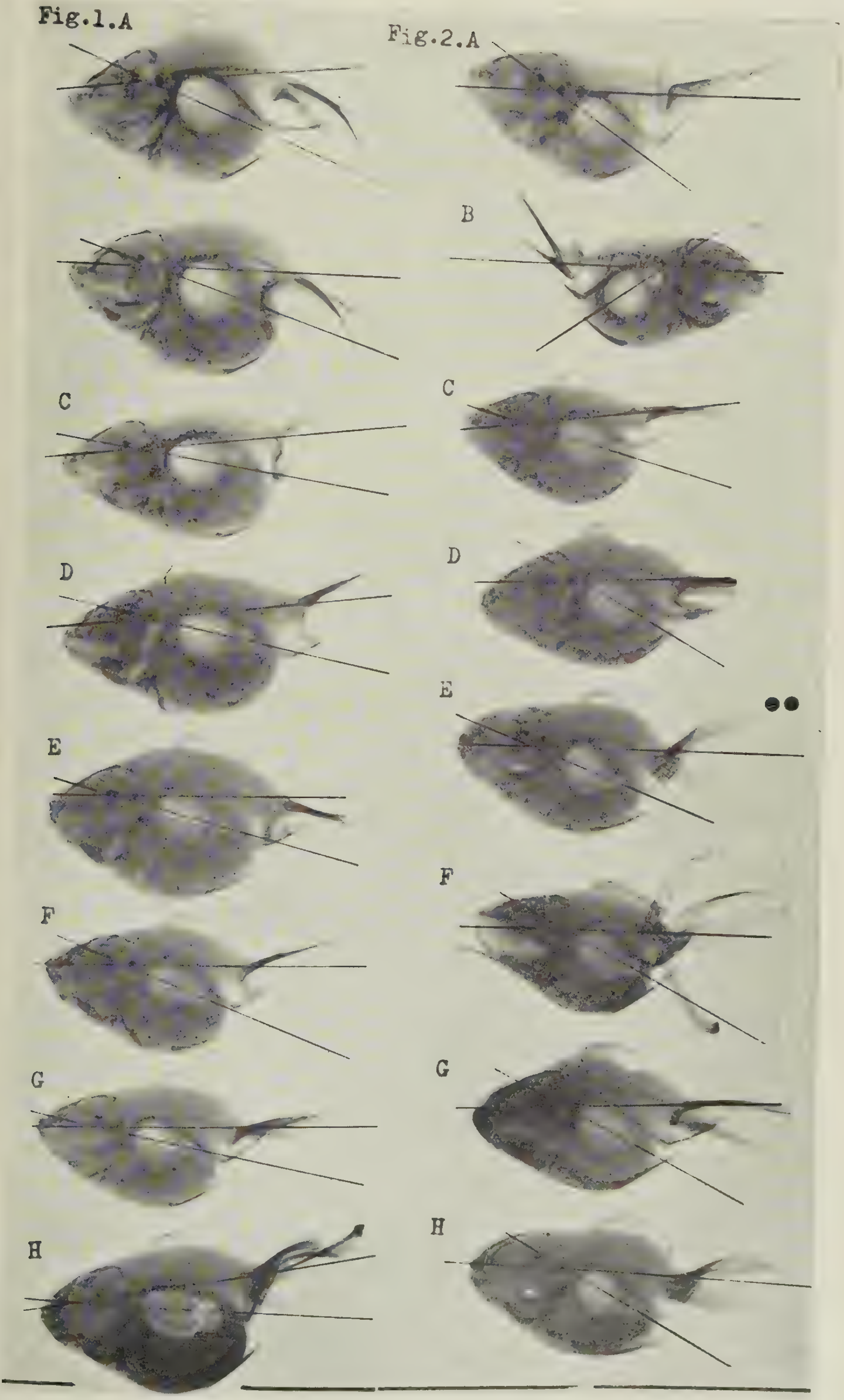
Fig.1.A
C
D
E
F
G
H
Fig.2.A
B
C
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H

Explanation of Plate XVIII

Fig. 1. A–H, showing the bladder angle of the swimbladders of normal *Ryukin*, a variety of goldfish.

Fig. 2. A–H, Showing the angle of the bladders of upside-down conditioned fish.

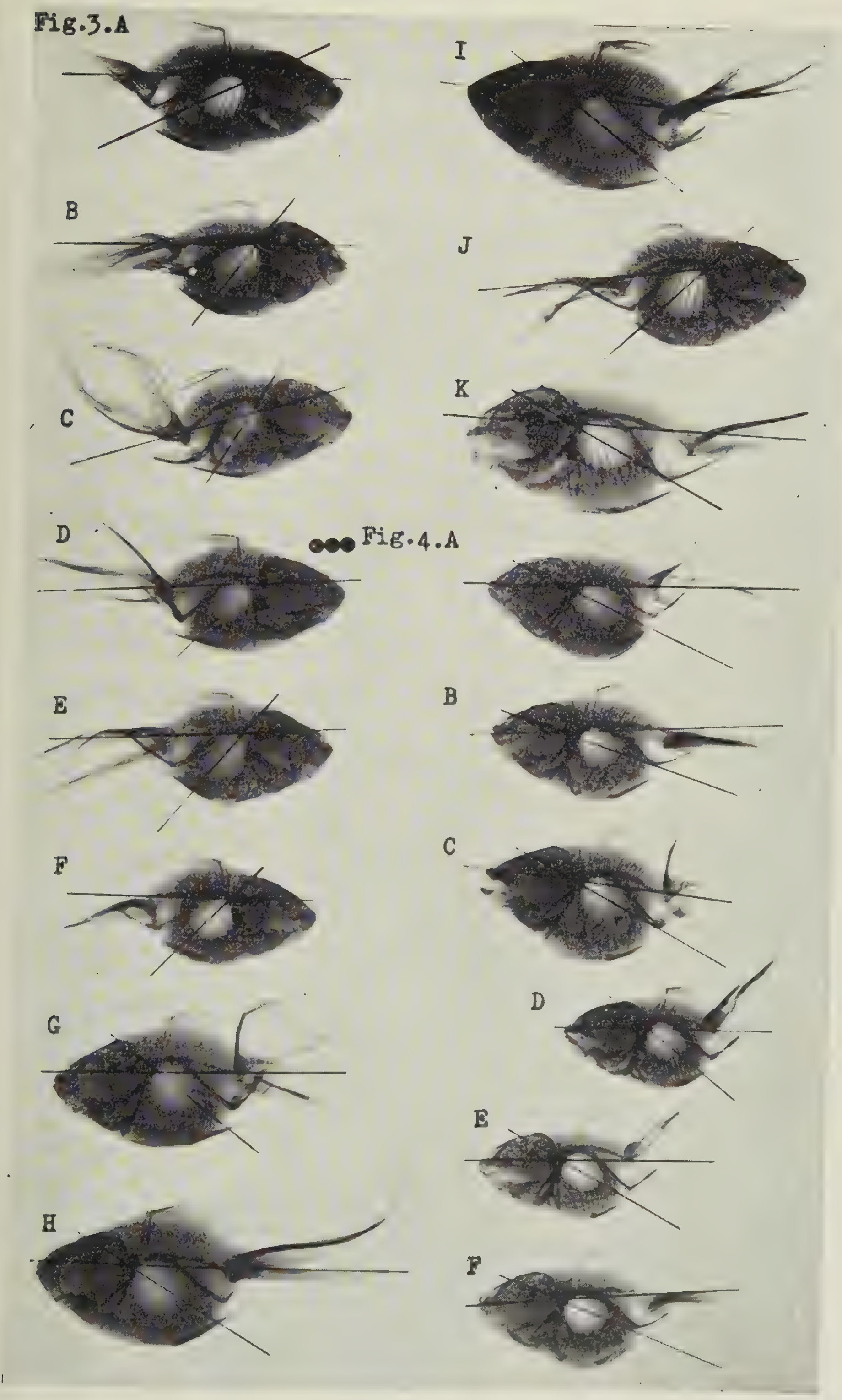
Fig.3.A
B
C
D
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G
H
I
J
K
Fig.4.A
B
C
D
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Explanation of Plate XIX

Fig. 3. A–K, showing the angle of the swimbladders of lateral inclined fish.

Fig. 4. A–F, showing the angle of newly recovered fish which in abnormal condition.

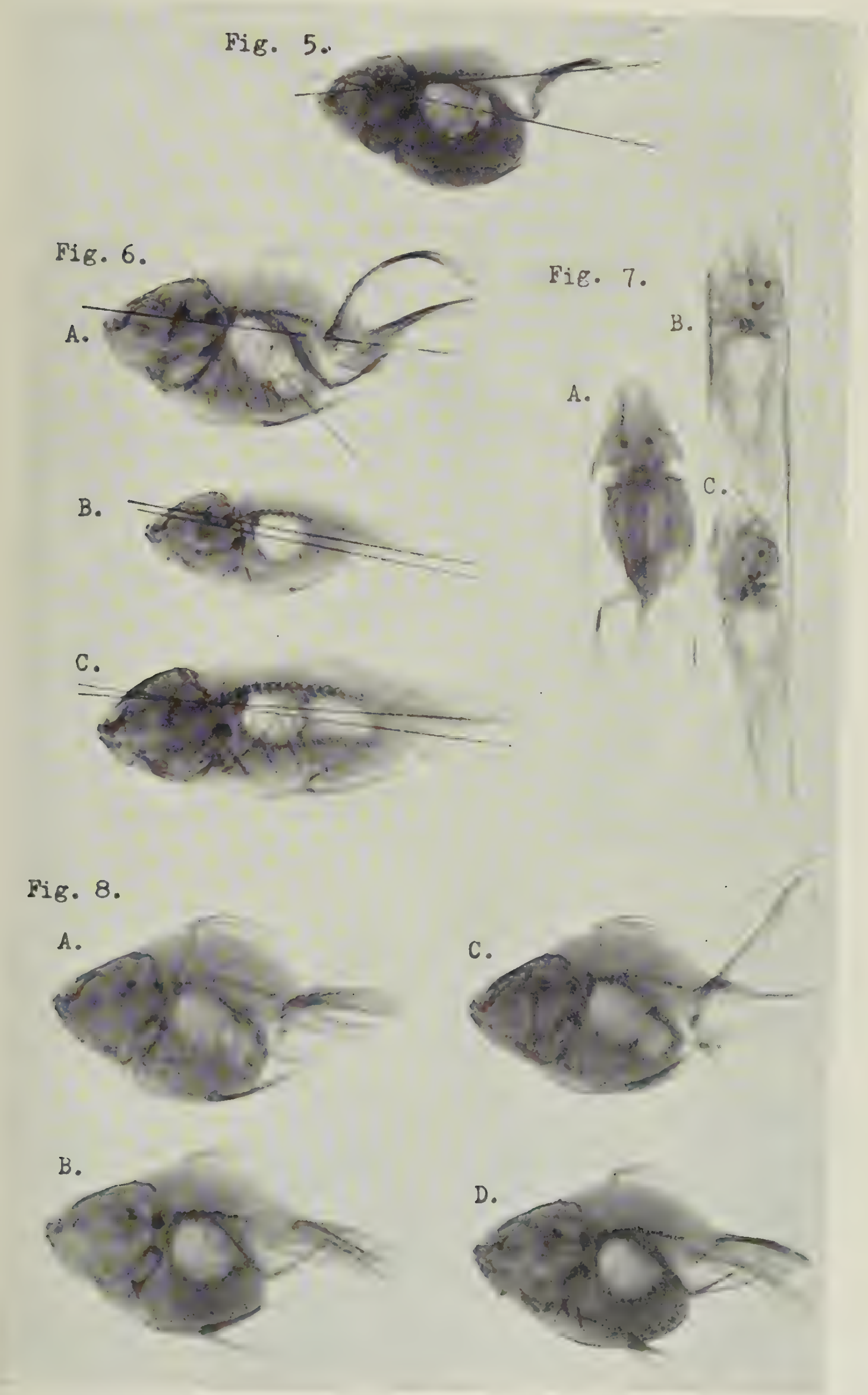
Fig. 5.
Fig. 6.
A.
B.
C.
Fig. 7.
A.
B.
C.
Fig. 8.
A.
B.
C.
D.

Explanation of Plate XX

Fig. 5. Showing the newly recovered fish which was ejected gases in the bladder by the vacum at the time of its upside-down condition.

Fig. 6. Showing the comparison of bladder angles between A. *Ryukin*, B. *Wakin* and C. *Sibunkin*.

Fig. 7. Showing the dorsal views of swimbladders of A. *Ryukin* containing inclined posterior lobe and of B. C. *Wakin* of normal bladders.

Fig. 8. Showing the effect of high concentrated salt water on the size of the swimbladders; A and B before, and C and D after putting in the 1.0% salt solution.

Fig. 9.
A.
B.
C.
D.
Fig. 10.
A.
B.
C.
D.
Fig. 11.
A.
B.
C.
D.

Explanation of Plate XXI

Fig. 9. A. B, C and D, show the normal swimbladdes of *Ryukin*.

Fig. 10. A. B. C and D, show the swimbladders in which a gasses were ejected at the same time by a vacuum pump.

Fig. 11. Showing the recovering of the bladder. A and B are the state of their being recovered to the normal in the aquarium. C and B were put into the aquarium which in a nylon net was set under the water surface preventing their absorbing the air from the surface; while C was somewhat vigorous and was recovered to the normal condition by swallowing oxygen produced by the carbon assimilation of the weeds, but D could not absorb gas because of its suffering too much damage with a vacuum.

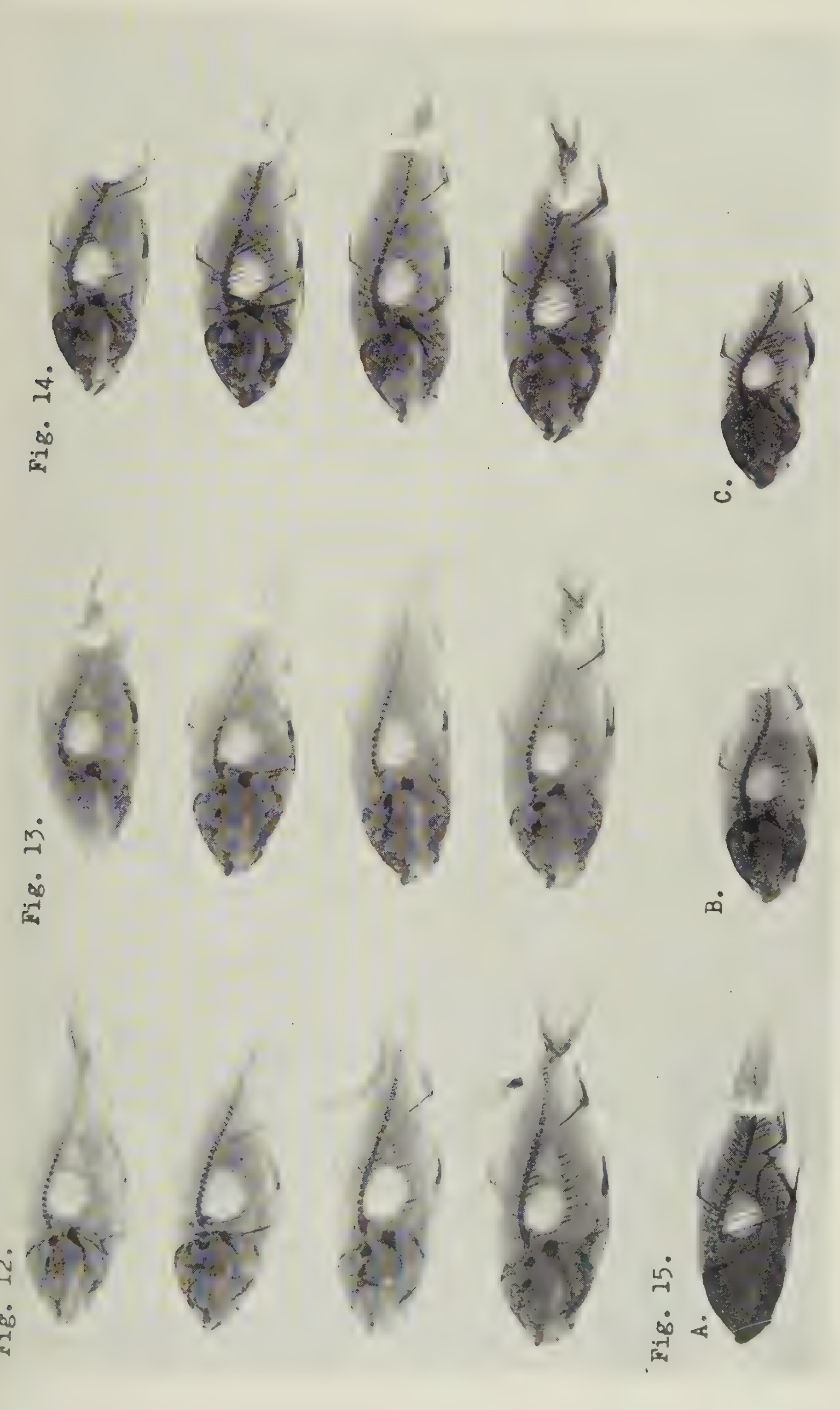

Fig. 12.

Fig. 13.

Fig. 14.

Fig. 15. A. B. C.

Explanation of Plate XXII

Fig. 12. Showing the normal *Wakin*.

Fig. 13. Showing the results of excluding caudal neurosecretory system by a heated needle.

Fig. 14. Showing the same condition after two days operation.

Fig. 15. A is a photograph taken on October 19th. B is taken on Octotber 27th. C is one on November 10th.

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Vol. 3, No. 3, December 15, 1960.

Analysis of Ecological Phenomena in the Community of Sessile Organisms (1)

Extinction of *Bugula neritina* LINNÉ and *Styela plicata* (LESUEUR) from the Community

(*With Plate XXIII and Text-figures 1–3*)

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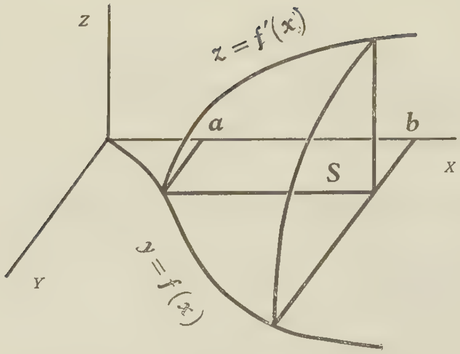
In any trivial form it may be presented, an ecological phenomenon may, strange to say, have a structure, using the word in the widest sense. The structure is related not only to the unit factors, such as time, space and others, but also to the rather simple events, such as number of occurring individuals, their growth and so on. Important in the ecological study is the disclosure of the relations which may exist among those factors, or events. This is especially the case with such a complicated phenomenon as presented by a fouling community, and this may be subservient to the comprehension of the changes which that community undergoes. In order to make the matter clear, the author (1944, 1954) published a diagram illustrating the change in a community, the "analytical graph".

Applying the graph to actual cases, he intends in this series of papers to disclose the constitution of ecological phenomena observable in various fouling communities. First, the phenomenon concerned with the process of the extinction of species from a community will be made the subject of the present article.

1. "Analytical graph"

The amount of fouling community developing within a certain area of substratum may be indicated, on one hand, by weight, or by volume. The numerical value expressed by either of these is apt to show a rapid change in relation to the lapse of time, for so-called "age composition" is negrected in this case. The quantity may be expressed, on the other hand, by the results of two events, i) that animals increase in their number and ii) that they grow as time goes by. The diagrammatic representation of the change in the quantity of fouling organisms was based on the combination of those factors (Text-fig. 1: published in 1944). In Text-fig. 1, x, y and z axes represent the time (days), the number of animals attached (individuals or colonies) and the extent of their growth (weight



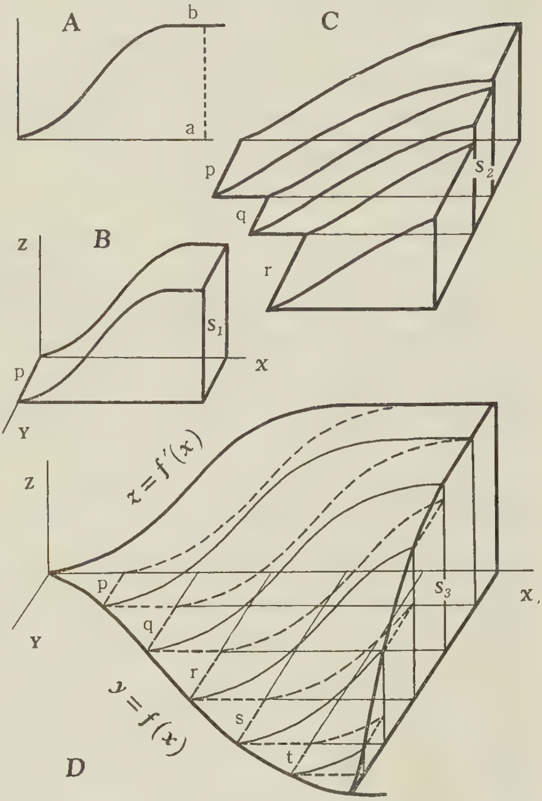
Text-fig. 1. Analytical graph on the quantity of fouling animals. x axis, days; y axis, number of individuals (in cumulative value); z axis, growth (in weight or volume). $y=f(x)$, curve showing the increase of animals in their number; $z=f'(x)$, growth curve. S, total quantity of fouling animals; a, b, time.

or volume) respectively. The curve $y=f(x)$ on xy plane stands for the cumulative increase of animals in their number and the curve $z=f'(x)$ is the growth curve. Series of growth curves starting from every point on the line y will form a deformed trigonal pyramid together with two planes xy and xz. In a population, which has commenced its development at the time a, its condition at the time b is represented by plane S which is the section of the pyramid parallel with yz plane. The "age composition" of the community may be shown at the same time by the shape of this plane.

The growth curve of an animal is ordinarily indicated by plane co-ordintes, the abscissa representing the time and the ordinate the growth (Text-fig. 2A). The extent of growth (in weight or volume) at the instant a is given by the ordinate ab. If we take the time, the number of animals and their growth on x, y and z axes and assume that there are p individuals which show the similar growth curves, their total weight or volume becomes p times of ab, that is the area of the plane s_1 (Text-fig. 2B). In other words, the total quantity of p individuals at a certain instant may be shown by the cutting surface of the prism which is derived from the growth curves as many as p. In a population, in which individuals increase in their number to q, r and further, the successive changes in the total quantity may be given by the addition of the similar prisms (Text-fig. 2C). The quantity of the animal at a certain instant is shown by the section s_2 of this compound prism. Since the increase of individuals in a population may proceed continuously, the prism representing the change of quantity may become a deformed trigonal pyramid (Text-fig. 2D). The plane s_3 indicates the quantity of animals consisting of p individuals which settled down on the first day and grew for n days, q individuals which settled down on the second day and grew for $(n-1)$ days, etc. The area of s_3 corresponds to the total quantity on the $(n+1)$-th day after the initiation of community.

2. Method

The experiment was carried out at Amakusa Marine Biological Station,



Text-fig. 2. Analytical graph showing the increase of animals. s_1, s_2, s_3, surfaces, cutting the solid formed by the series of growth curves vertically to x axis. A: growth curve. ab, extent of growth. B: growth of p individuals. x, y and z as in Text-fig. 1. s_1, total quantity of p individuals. C: quantity of population increasing with time. p, q, r, number of individuals. s_2, total quantity. D: continuous change of population. x, y, z, $y=f(x)$ and $z=f'(x)$ as in Text-fig. 1. p, q, r, s and t, number of individuals having settled down at respective instants. s_3, plane representing with its area the quantity of animals, with its shape the age composition.

Kyûsyû University, located at Tomioka, Amakusa, Kumamoto prefecture. Concrete cubic blocks 30 cm×30 cm×2 cm or 20 cm×20 cm×1.5 cm in size were suspended by the aid of ropes from a raft which was launched in the sea in front of the station and were submerged one meter below the surface. They were immersed one in every ten days. A device for directing one of their faces always to the south was carefully undertaken. The organisms having attached to this side of the blocks were examined every five days and their sites, shapes and sizes were exactly reproduced on a map by hand drawing. Photographs were taken every ten days. The regularity, however, was frequently interrupted not only for the bad weather but also for the author's private affairs. Moreover, on account of the diversity in the abundance of organisms and of variation in their growth rate, immersion of blocks over ten days was sometimes meaningless, or it was forced sometimes to cover six months or more.

Measurement and phtographing were taken as the organisms were alive in an aquarium constantly supplied with running water. Much precaution was taken against keeping the organisms healthy so as to ensure their living after their transfer to the sea.

Although the data obtained by the experiment, which was continued from 1944 to 1950 with an interruption in 1945, have reached a considerable amount, they will be retained, for the greater part, for the use in another report now in preparation and only a small part of them is employed here in case of need in discussing the subject.

3. Observation

In such organisms as sedentary diatoms, hydroids, compound ascidians, *Bugula neritina* LINNÉ and *Styela plicata* (LESUEUR), their extinction from a community takes place in a rather short time. Of them, *Bugula neritina* shows the most characteristic progress of extinction, while *Styela plicata* makes a contrast.

In 1946, at Tomioka, *Bugula* began to settle down on the blocks early in April, being abundantly found from May onward. Earlier settlers came to maturity in June and laid their eggs, the larvae increasing thus more and more in their number. The substratum was densely covered in this month by full-grown colonies attaining several cm in height (Pl. XXIII, Fig. 1). Nevertheless, in the second decade of July, owing to their abrupt destruction effected by the rise of temperature to 26°–27°C or more, the substratum became almost destitute of them (Pl. XXIII, Fig. 2). Their extinction took place equally for both old and young.

The abundant attachment of *Styela plicata* was found accompanied by that of *Bugula* (Pl. XXIII, Fig. 1), though this did not belong to the occurrence of every year. Still continuing the growth after the destruction of the latter, which took place in the middle of July, the former was dominant over other animals constituting the community in the second decade of August (Pl. XXIII, Fig. 2), and yet became extinct in October. The substratum was thus largely denuded (Pl. XXIII, Fig. 3). Disappearance of *Styela* was rather gradual in contrast to the abrupt one of *Bugula*. The corresponding phenomenon which may take place in *Styela* established in autumn is left unobserved.

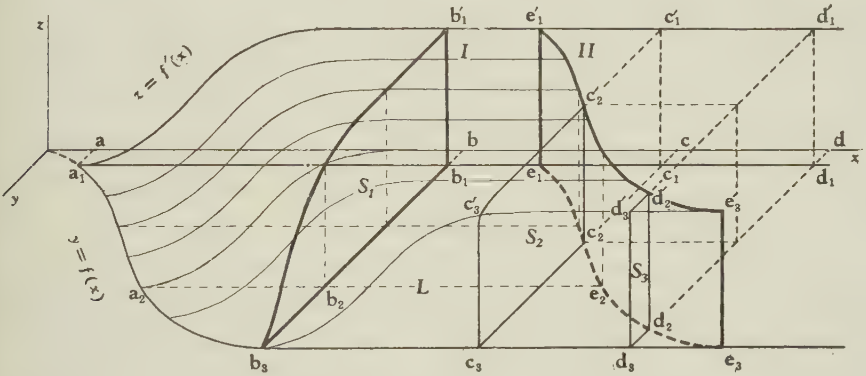
4. Analysis of ecological phenomena

Two different types in the extinction of species as mentioned above may be explained on the analytical graph in the following way.

Type I: The type in which abrupt destruction of all the colonies or individuals of a species occurs in a certain developmental stage of community. In Text-fig. 3, where x, y and z axes are taken in the same way as above and the curves $y=f(x)$ and $z=f'(x)$ are drawn with the similar significance, abrupt

destruction occurring at the time b is represented by the plane $b_1b_3b_1'$ (hereafter referred to as Plane I), which is parallel with yz plane.

Type II: Natural death of individuals occurring one after another brings about the decline of species from the community. In Text-fig. 3, each individual



Text-fig. 3. Graph illustrating the extinction of species in a community. x, y, z, $y=f(x)$ and $z=f'(x)$ as in Text-fig. 1. a, b, c, d, four instants in the course of change; I, II, surfaces representing Type I and II of extinction; L, duration of life; S_1, S_2, S_3, three sections indicating the state of population at the instants b, c and d.

commencing its life at the point on the curve y (e. g. a_1, a_2 etc.) meets its end at another end (e_1, e_2 etc.) of the line indicating its span of life (L). As $a_1 e_1 = a_2 e_2 \cdots = L$, the curve of the extinction of species constituted by the points $e_1, e_2 \cdots$ may be parallel with y curve indicating the increase of individuals. State of things observable in the extinction of species is, therefore, indicated by the curved surface $e_1 e_3 e_3' e_1'$ in this case (Plane II). Quantity of the species at the instant c, at which the extinction is proceeding, may be represented by the area $c_2 c_3 c_3' c_2' (=S_2)$, for this stands for the remainder of the subtruction of the area $c_1 c_2 c_2' c_1'$, which is equivalent to the quantity of dead animals, from the area $c_1 c_3 c_3' c_1'$, which corresponds to the same of all the animals in the ideal case of their perfect survival. Quantity at the instant d later than c is likewise shown by the area $d_2 d_3 d_3' d_2' (=S_3)$. In case there should be no renewal of attachment, the population will gradually be reduced in quantity, as this may be seen from the fact that S_2 at the time c passes at a later time d to S_3 and finally to the complete disappearance at e_3.

5. Consideration

According to MAWATARI (1951), the large colonies of *Bugula neritina* are torn to shreds by the storms of winter, only smaller and younger ones remaining in spring, though in inactive state. Similarly at Woods Hole, it was said that most of the larger colonies of *Bugula flabellata* were killed during the

winter, but the small ones survived, on the basis of which the species showed a vigorous flourishing in next June (GRAVE, 1933). These appear to point to the presence of another type of extinction in *Bugula* colonies. This might be the case with *Styela plicata*, but in so far as the extinction of the individuals having settled down in autumn is left unexamined, it can not be insisted with any certainty. The present article does not give the detailed informations about the extinction of those species, but is confined to deal with an extinction which was observed in a certain season of a year.

In Type I, the duration of life is different according to individuals, for they die synchronously in spite of the diversity in the time of their attachment. In animals whose span of life is rather short and is restricted within a year or so, this type of extinction may occur in a definite season. In Type II, all the individuals possess the same length of life. Diversity of the time of their settlement naturally brings about that of the time of their senile death. Typically, this type may be met with in the animals whose life lasts so long a time as to be appropriately measured by year. In this case, the extinction does not so much depend upon the direct influence exerted by the seasonal change of external factors as upon the exhaustion of internal vitality.

Characteristic phenomenon observable in each of the types in the extinction of species can be made out by the peculiarities of the above-mentioned two planes. In Type I, difference in the resistance to the environmental factors between old and young animals may make Plane I incline to xz plane, or make it wavy according to circumstances. Since in the animals living long Plane II covers several years, the seasonal differences in their decay result in the partial undulation of the plane, though these do not extend so far as to alter its general shape. The two types alluded above representing extreme cases, there may be a lot of intermediate types corresponding to various short-lived animals. Extincion of *Bugula neritina* named above belongs to the typical case of Type I and that of *Styela plicata* is nearly allied to Type II, though this belongs to a short-lived animal.

Résumé

1) The present article gives a contrivance which illustrates the extinction of species from the community of sessile organisms on the "analytical graph" published by the author in Japanese (1944, 1954).

2) Regular examination of the organisms having attached to the submerged test blocks revealed that two different types are perceptible in the extinction of species. In some species almost all the members were abruptly extinguished within a short time (Type I), while in the other they disappeared rather gradually one after another (Type II).

3) In the analytical graph, the two types are represented each by a plane cutting the pyramid surrounded by *xy* and *yz* planes as well as by the one formed by the series of growth curves. Plane I perpendicular to *x* axis represents Type I and Plane II which is oblique and undulated stands for Type II.

4) Type I is found in the species the decay of which is caused by some environmental factors, whereas Type II shows the death resulted from senescence. Various forms in the extinction of species from community can be represented by similar cut surface which makes with *x* axis an angle intermediate between that of surface I and that of II.

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Explanation of Plate XXIII

Photographs showing successive changes of fouling community.

Fig. 1. *Bugula neritina* and *Styela plicata* both in flourish (June 30, 1946; 90 days after the immersion of the block).

Fig. 2. Abrupt decay of *Bugula neritina* in contrast to healthful survival of *Styela plicata* (August 9, 1946; 130 days after the immersion).

Fig. 3. Gradual decline of *Styela plicata* (October 2, 1946; 180 days after the immersion).

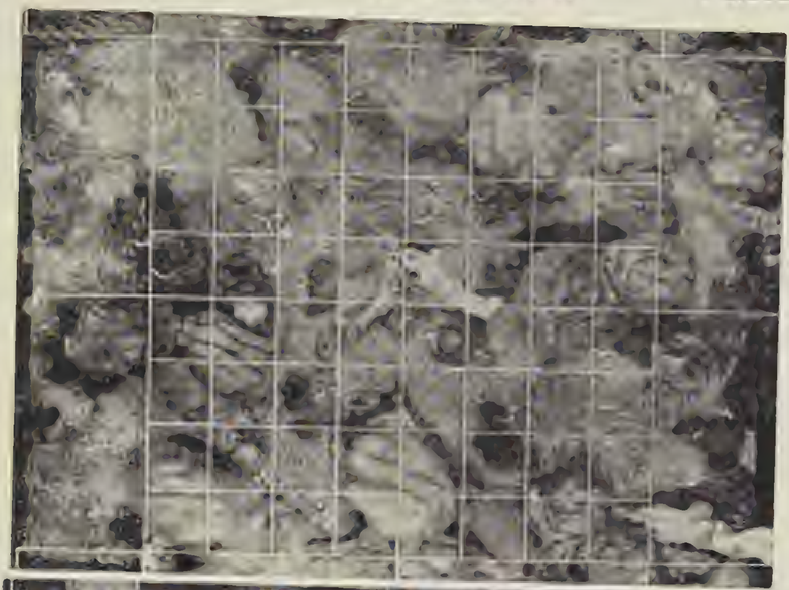

Fig. 3.

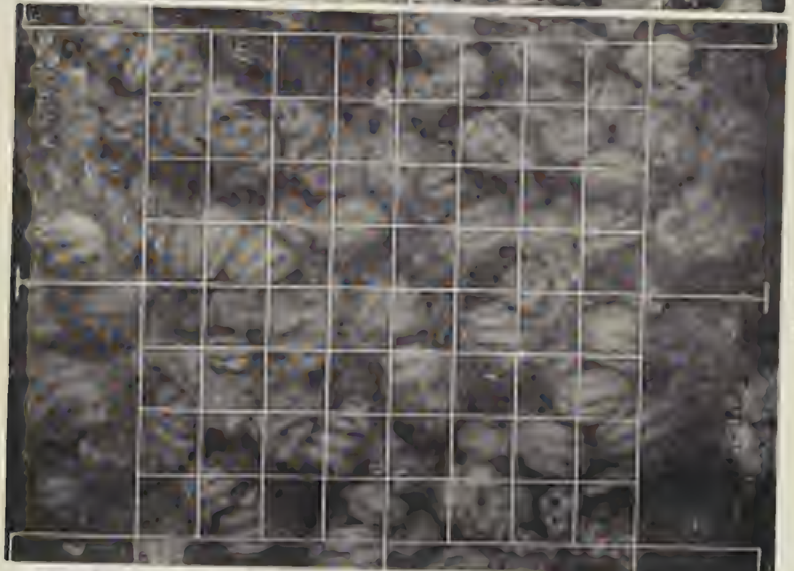

Fig. 2.

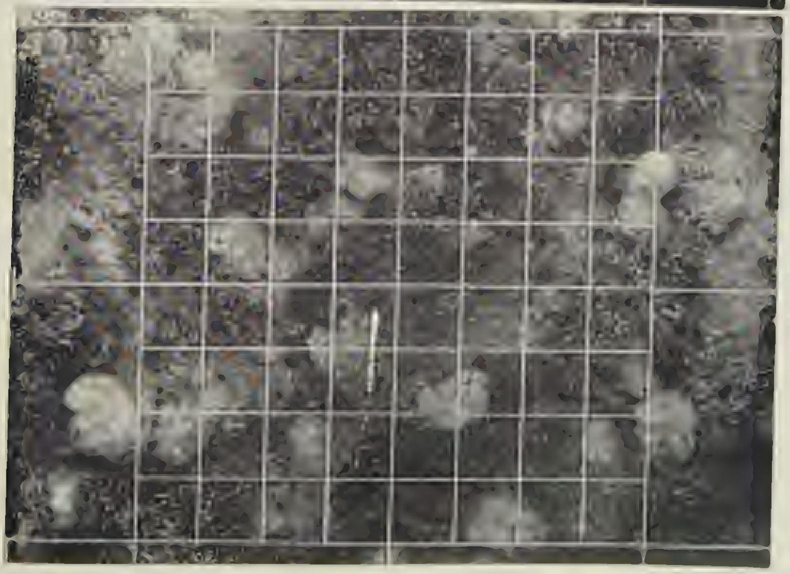

Fig. 1.

Report of Faculty of Fisheries,
Prefectural University of Mie,
Vol. 3, No. 3, December 15, 1960.

Analysis of Ecological Phenomena in the Community of Sessile Organisms (2)

Growth, Maturation and Propagation in *Bugula neritina* LINNÉ

(*With Text-figures 1-3 and Table 1*)

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In the foregoing article (1) the author has given a brief note on the analytical graph, on which he has shown two different patterns in the extinction of species from a community. He is here intending to make another report on the phenomena observable in the community in connection with the maturation of the colonies of *Bugula neritina* and with the change of number of their youngs which have succeeded in attaching themselves to the substratum.

1. Method

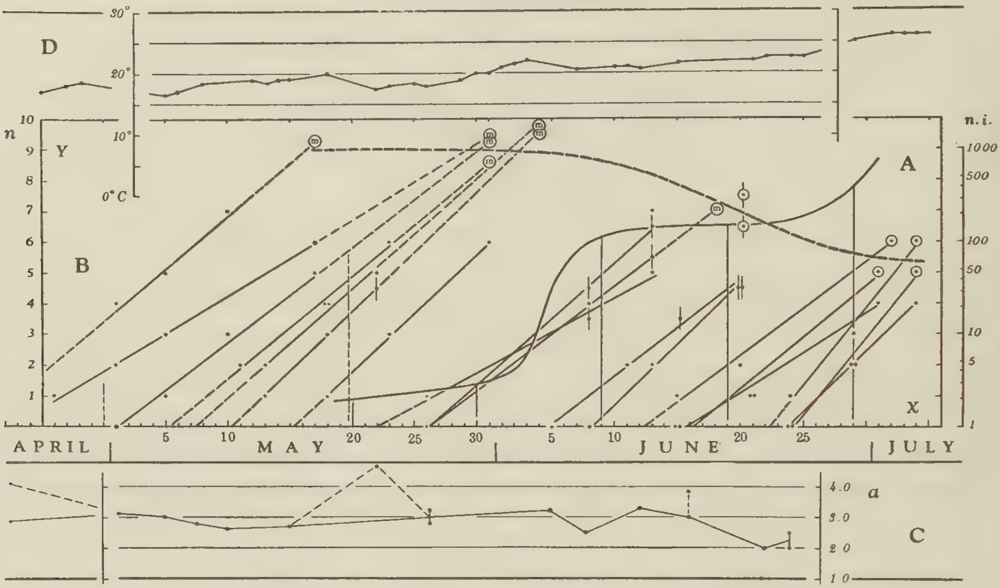
The data here dealt with were obtained by the experiment made in 1944 in the neighborhood of Amakusa Marine Biological Station, Kyûsyû University. As the substrata for the attachment of organisms, test-blocks made of concrete 30 cm × 30 cm × 2 cm in size were suspended from a raft and submerged at a depth of 1 m. Fifteen blocks were immersed one by one at intervals of ten days during the season from the beginning of April to the middle of July. Out of numbers of organisms having attached to them with the lapse of time, a bryozoan *Bugula neritina* LINNÉ was made the object of the study. It was examined in every five days with respect to its number occurring on the block surface confined within the area of 20 cm × 20 cm.

2. Observation

Although a number of young *Bugula* showed attachment to the test-blocks in April, most of them were found dead before maturation, except those adhered late in the month. From this month onward, settling youngs became larger and larger in their number until they reached the greatest abundance in early July, when almost all the growing colonies, both old and young, were abruptly destroyed by a high temperature (KAWAHARA, 1944, 1960).

In May, the youngs found on the block five days after its immersion were still rather small in their number, being restricted to two or three within

the area of 20 cm×20 cm, but from then on they incessantly increased. They were 114 on 9 June, 152 on 19 June and attained as many as 385 on 29 June. The change of number in the settling youngs is indicated in Text-fig. 1A by two



Text-fig. 1. Relation between the maturation of colony and the number of settling larvae in *Bugula neritina*.

A: Increase of larvae in accordance with the progress of season. x axis, days; y axis, number of larvae attached, (*n.i.*). Length of vertical solid line, number of youngs found on block within the area of 20 cm×20 cm five days after its immersion on the correspond-ng date. Length of vertical broken line: number found after following 15 days. Curve in solid line: seasonal change in the attachment of youngs.

B: Reductional tendency of the length of time requisite for maturation. x axis; days elapsed; y axis, growth index, (n). Diagonal lines, growth rate of colony. Dot, immature colony; same enclosed by circle, mature colony; "m" enclosed by circle, mature colony, with growth index unknown. Short vertical lines above and below the dot: range of variation of growth. Curve in broken line: arrest of growth in precocious maturation.

C: a same as that of $x=ay+b$ in Text-fig. 1B. Broken lines, abnormalities; short vertical bar, range of variation. Points correspond with the dates of initiation of growth of colonies shown in Text-fig. 1B.

D: Water temperature during the period of experiment.

series of verticals, one drawn in solid lines and the other in broken ones. The length of solid lines represents the number of young colonies found within the area of 20 cm×20 cm five days after the immersion of the block and the same of broken lines shows the number added during succeeding 15 days. As may be seen from the curve (in solid line) combining the upper ends of those lines, the change in the number comprises three gradations distinct one from another with abrupt ascents occurring at the beginning and the end of June.

The most typical growth of *Bugula* colony, which could be observed about

the second decade of June, consisted in the repetition of dichotomous ramification (Text-fig. 2). Accordingly, it was considered appropriate to take the number of times of the ramification n as the growth index. If all of the successive stages were plotted on co-ordinates, in which the days required for the colony to reach the respective stage were taken on x axis and the growth index on y

Text-fig. 2. Representative growth in the colony of *Bugula neritina*. A, change in the configuration of colony; B, growth index, (n); C, days required.

axis, they would lie on a straight line, $x=ay+b$ (where a is the regression coefficient and b the constant). In such a treatment, the growth rate of the colony would be represented by the inclination which this line makes with the y axis.

Variations in the growth rate of *Bugula* according to seasons are listed in Table 1, which is diagrammatically represented by diagonal lines in Text-fig. 1B. Dots and the same enclosed by circle in the figure represent respectively the immature and mature colonies and both the lots indicate with their co-ordinates the date of observation and the extent of growth. Circles enclosing "m" are the mature colony, the ramification of which are left unexamined. Upper and lower short vertical lines associated with the dots indicate the range of variation in the ramification. It may be perceivable from the figure that it takes about 30 days for the colonies established about the end of April to attain to maturity and about 25 days for those established about the middle of May. The length of time required for the animal to reach maturity grows further shorter as the season advances. It is reduced from 20 days to 10–15 days during the period from the beginning or the middle of June to the end of this month. Accordingly, the attachment of the larvae derived from three successive generations can frequently be observed before the midsummer arrives. This coincides with the fact that three gradations occur in the increase of number of youngs on the block.

In the equation representing the growth rate, $x=ay+b$ (Text-fig. 1B), the regression coefficient a is almost constant, its numerical value being maintained at about 3.0 throughout the middle of June, in spite of the gradual ascent of water temperature from 17°C to 22°C (Text-fig. 1D). Nevertheless, at about the end of June, when the temperature rises to 25°C or more, the value of a becomes reduced to about 2.0 (Text-fig. 1C). Undergoing likewise a regressive change, the growth index which is 8–9 during the term from late May to early June

Table 1. Various cases of growth in the colony of *Bugula neritina*: date means the one on which each colony attained to respective stage; boldface, mature colony.

<table>
<tr><th>Growth index (n) / No. of specimen</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>Unex-amined</th></tr>
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<tr><td>6</td><td></td><td>May 13</td><td></td><td>May 18</td><td colspan="2">May 22</td><td></td><td></td><td></td><td>Jun. 4</td></tr>
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<tr><td>15</td><td>Jun. 8</td><td></td><td>Jun. 13</td><td></td><td colspan="2">Jun. 20</td><td></td><td></td><td></td><td></td></tr>
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<tr><td>17</td><td>Jun. 16</td><td>Jun. 21</td><td></td><td></td><td></td><td>Jul. 1</td><td></td><td></td><td></td><td></td></tr>
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<tr><td>19</td><td></td><td>Jun. 24</td><td></td><td>Jun. 29</td><td></td><td></td><td>Jul. 4</td><td></td><td></td><td></td></tr>
<tr><td>20</td><td>Jun. 24</td><td></td><td>Jun. 29</td><td></td><td></td><td>Jul. 4</td><td></td><td></td><td></td><td></td></tr>
<tr><td>21</td><td>Jun. 24</td><td></td><td>Jun. 29</td><td></td><td>Jul. 4</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

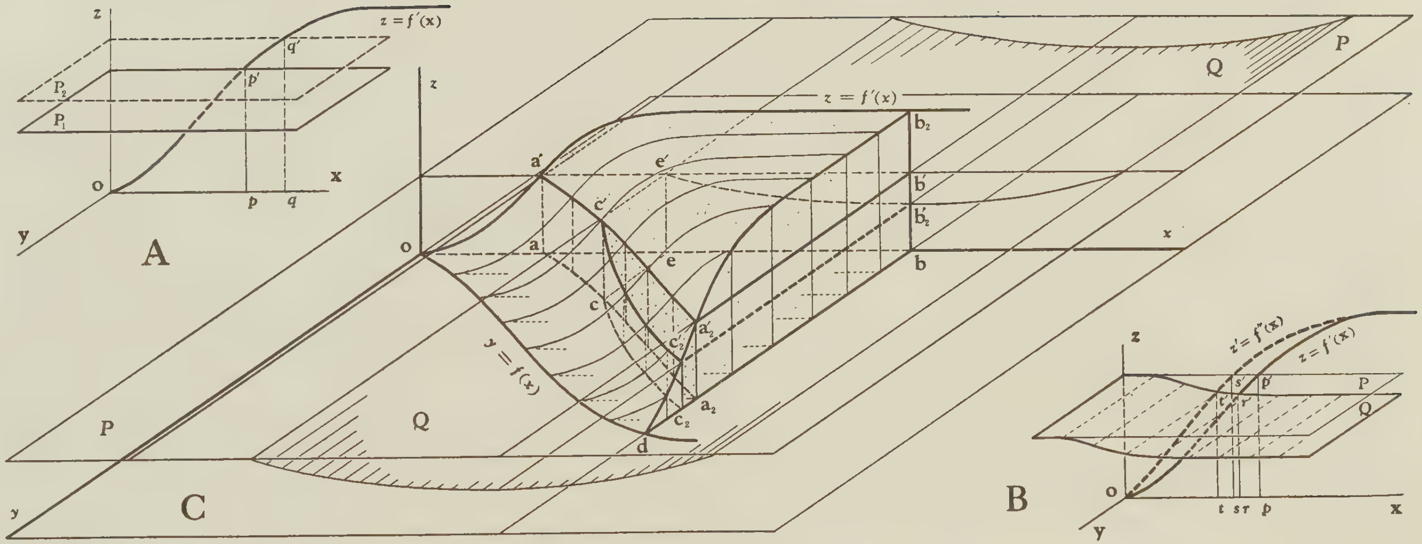
decreases, past 6–7 of the middle or the end of June, to 5–6 in early July (Text-fig. 1B, broken curve). It may, therefore, be concluded that the shortening in the duration of a generation chiefly results from the prematurity; that is, the colony shows a tendency to attain to maturity in a smaller size in the warmer season than in the colder. Acceleration in the growth rate occurring from late June on may give an additional effect upon the increase in the number of youngs.

3. Application of analytical graph to actual instances

Relations existing among factors and events taking part in the manifestation of the above-mentioned phenomenon can be diagrammatically demonstrated by the analytical graph (Text-fig. 3). Generally considered, the stage at which an animal attains maturity can be indicated by a point p' on its growth curve $z=f'(x)$ (Text-fig. 3A). So far as all the individuals in a population of that animal commence their growth from xy plane (x, days elapsed; y, number of individuals), the points corresponding to p' on the growth curves of all of them may form another plane P_1 which is parallel with xy plane. The distance between the two planes (pp') represents the extent of growth when the animals attain to maturity after the lapse of time op. In other words, an animal whose growth curve makes a start from any point on the xy plane may sexually mature at the point of intersection of the curve with the plane P_1. Another plane P_2 can be considered for another character.

Relation between the growth curve and the length of time requisite for maturation and change in the plane of maturity due to some cause are now to be considered (Text-fig. 3B). In case there should be a tendency in the animal sexually to mature in a smaller size of body, the plane of maturity comes to lie nearer to xy plane than in normal case, as represented by the curved surface Q (plane of prematurity). In the normal rate, the growth curve $z=f'(x)$ intersects the plane of normal maturity P at the point p' and the plane of prematurity Q at r'. When we denote the feet of perpendiculars drawn from p' and r' to xy plane with p and r, the lengths of time requisite for normal and precocious maturation correspond to op and or. There exists between them a relation, that $or<op$. In an acceleration of growth as in $z'=f''(x)$, the points corresponding to p, r, p' and r' in normal growth are denoted by s, t, s' and t' and the lengths of time necessary for maturation are indicated by os and ot. Comparing the normal growth with the accelerated one, we can find the relations that $ot<os$, $ot<or$, and $os<op$. Accordingly, $ot<or<op$ and $ot<os<op$.

If we consider the population of colonies in *Bugula neritina* after the way as in the foregoing, we will get Text-fig. 3C. As described in the preceding article, the series of growth curves $z=f'(x)$, which make their start on the line $y=f(x)$ representing the increase of colonies, will form together with two co-ordinate planes xy and xz a deformed pyramid, one side of which corresponds to the curved surface formed by them. In the region above the plane P the growth curves mean that all the colonies are mature. When we take the area $a'a_2'b'$ as the section of the pyramid by the plane P and aa_2b as its orthogonal projection on xy plane, we may be able to assert that the regions of growth curves lying up above the area aa_2b indicate the maturity of colonies. At the instant



Text-fig. 3. Analytical graph of a population of *Bugula neritina*. x axis, days; y axis, number of colonies; z axis, growth. $y=f(x)$, increase in the number of colonies; $z=f'(x)$, their growth curves.

A: Plane of maturity. p', point of maturity; p, time required; pp', extent of growth; op, lapse of time. P_1, plane parallel with xy plane; P_2, another plane representing another character. q', q, qq', oq, corresponding to p', p, pp' op of plane P_1.

B: Normal and precocious maturation. P, plane of normal maturity; Q, same of precocious maturity. $z=f'(x)$, growth curve of normal rate; p', r', points of intersection of the curve z with the planes P and Q. $z'=f''(x)$, growth curve at an accelerated rate; s', t', points of intersection of curve z' with the planes P and Q. p, r, s, t, feet of perpendiculars from p', r', s', t'.

C: "Analytical graph". a, e, b, time on x axis; P, Q, as in Text-fig. 3B; $a'a_2'b'$, the area on the plane P cutting across the pyramid formed by the series of curves, $z=f'(x)$; aa_2b, orthogonal projection of the area $a'a_2'b'$; $e'c'c_2'b_2'$, plane of intersection of the pyramid with the curved surface Q; ecc_2b, orthogonal projection of the surface $e'c'c_2'b_2'$.

b, the ratio of their number to that of immature colonies is ba_2: a_2d. Now let us assume the plane P to be turned into Q for some cause at the instant e. The section of the pyramid by Q is the area $e'c'c_2'b_2'$ and its orthogonal projection on the xy plane is another area ecc_2b. The growth curves lying above ecc_2b represent that the colonies are mature. Increment due to prematurity is, accordingly, represented by the prism $cc_2a_2c'c_2'a_2'$. At the instant b, numerical ratio between mature and immature colonies becomes $ba_2+a_2c_2(=bc_2):a_2d-a_2c_2$ $(=c_2d)$.

Productivity of larvae in a colony may be considered to be proportional to the extent of growth surpassing the plane P. In precocious maturation, this plane becomes to show a downward flexure as represented by the plane Q, so that the productivity may be given by the sum of the extent of normal maturation and the same of precocious one.

As heretofore described, it ought to be admitted that the increase in the number of *Bugula* youngs is a sum of the effects of the following four events. i) With the modification of plane P into a curved surface Q which is nearer to the xy plane, the mature colonies increase in their number from ba_2 to $ba_2+a_2c_2$. ii) In each colony the prematurity has an advantageous effect upon the productivity of larvae which becomes larger at the instant b from $b'b_2$ to $b'b_2+b'b_2'$ in proportion to the acceleration of maturation. iii) From the end of June onward, owing to the accelerated growth which makes the growth curve $z=f'(x)$ meet the plane P in an earlier phase, a_2c_2 becomes larger in value than in the normal. iv) Increase of liberated larvae effected by those three causes makes the curve $y=f(x)$ steeper and results in the enlargement of the value of $ba_2+a_2c_2$.

As concerns the relation of the axes between Text-fig. 1A and 3C, x and y axes are taken for the similar items, while the curve $y=f(x)$ in the latter represents the cumulative increase of the numerical values shown by the continuous curve in the former. In Text-fig. 1B, y axis corresponds to z axis of Text-fig. 3C. The broken curve of Text-fig. 1B indicates the details of the curvature of the surface Q of the latter, though the unit for growth is differently taken.

4. Consideration

It has been noticed by a number of authors that during the summer time the attachment of *Bugula* larvae is ceased, or, at least, reduced (Tokuoka, 1940; McDougall, 1943; Miyake, 1943; Kawahara, 1944; Mawatari, 1951, 1954), though the date and the duration of cessation or reduction are variable according to cases. At Amakusa, discontinuity in the season, in which the larvae settle down, begins in early July and ends in late August. Sequence of changes in

their number is of quite different nature between the seasons before and after that discontinuity. Although the "analytical graph" inserted above is founded on the observation made prior to the discontinuity, it may also be applicable to the state succeeding to this.

The growth rate and the length of time requisite for the maturation of *Bugula neritina* have been reported by MAWATARI (1951). The data here dealt with are much different from those given by him, for the former were derived from the observation made during the transition of seasons. This is the reason for which the foregoing characteristic phenomenon was recognizable.

Needless to say, a certain stage in the course of growth of an animal can be told by a point on its growth curve, but in a population it is not always easy to demonstrate the way in which the stage in question is manifested. The present study may give a clue for the solution of this problem by the use of analytical graph, in which a certain definite stage of the animals in the population is represented by a plane apart from xy plane for a certain definite distance. A change appearing in the stage may, therefore, be given by the alteration of the position and shape of that plane.

The above-mentioned increase of *Bugula* youngs may be explained as in the following. Approach of the plane of maturity to xy plane (i) and acceleration of growth rate (iii) have the time length requisite for maturity shortened, and this is followed by the increase of mature colonies. Productivity of larvae in each colony is proportional to the progress of maturity, being represented by the sum of the effects of two kinds of maturation, normal and precocious (ii). Abrupt increase of the attached youngs is effected (iv) by the synthetic action originating in the incease of mature colonies (i and iii) and of the larvae liberated from them (ii). This results in another increase in the attachment of larvae, which exerts in turn an effect upon three events named above (i), (iii) and (ii). Abundant attachment of larvae occurs at Amakusa in early July in this way.

Résumé

1) The experiment made in 1944 during the period ranging from April to early July showed that the larvae of *Bugula neritina* attach themselves to the test-blocks in increasing degree with the lapse of time and that the increase comprises three distinct gradations. Rapid increase of the larvae in warmer season is mainly effected by the shortening of the duration of one generation, which results in precocious arrival of maturity.

2) Relations existing among factors and events concerned with that phenomenon were analyzed by the use of analytical graph. A clue for solving

the problem consists in finding on this graph the plane which represents a definite stage of development.

3) The phenomenon associated with the increase of *Bugula* larvae is explained as in the following way. Approximation of the plane of maturity to *xy* plane is accompanied in the midsummer with a higher rise of growth curve. Synthetic effect of the two events results in an earlier arrival of maturity, which in turn gives rise to the increase of mature colonies. Number of larvae liberated from them is increased by the prematurity. Abrupt rise of the number of larvae arises from those two kinds of increases of different origin. It exerts, consequently, an additional effect upon the increase of the attachment of youngs.

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Vol. 3, No. 3, December 15, 1960.

On the Constitution of Marine Fouling Communities at Various Depths in Ago Bay

(*With Text-figs. 1-6 and Tables 1-5*)

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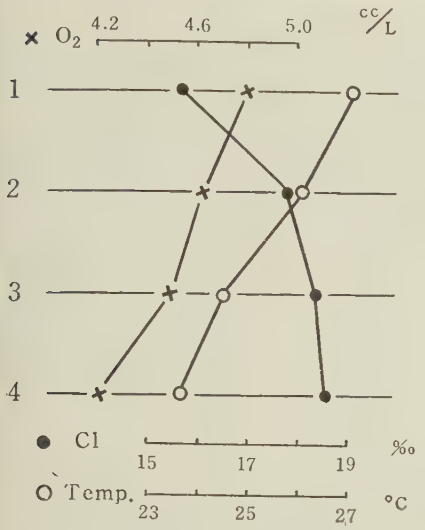
The present study which deals with the vertical dissimilarities in the composition of fouling communities is based on the experiment carried out in 1958 at Tatoku in Ago Bay, Mie prefecture. As the depth coming into question extends beyond the whole range in which the pearl oysters cultivation is carried on, the results obtained will add some contributions to our knowledge on the fouling of the oyster farms.

The study was enabled by a grant from the fund of Mie Prefecture for the research of pearl oyster culture, for which the authors wish to express their sincere gratitude. Acknowledgement is also due to Mr. K. TAKAYAMA, Director of National Pearl Research Laboratory for supplying various facilities in making their work at Tatoku Marine Station attached to the Laboratory and for placing the various data on the environmental factors at their disposal.

I. Method

As the substrata for the attachment of animals, cubic concrete blocks 20 cm wide, 20 cm long and 1.5 cm thick were used. Four blocks combined together by ropes in line were suspended in the sea, being kept one from another at the distance of 1.5 m, and their broadest faces were vertically maintained. The upper borders of the four were laid at the depths of 0.5 m, 2.0 m, 3.5 m and 5.0 m. The broadest faces of the block were of different nature, one smoothed with cement coating, while the other roughened without any coating. Although four sets of four blocks were first prepared, one of them was accidentally destructed. In order to see the effect of the qualitative difference in substrata, the smooth side of blocks were directed to the south in two sets and to the north in the rest.

Test blocks twelve in all were immersed in the water during four weeks ranging from July 10 to August 7. When removed from the water, they were instantly photographed and then brought to our University so as to be preserved in formalin. Detailed examination of organisms which have attached to the side facing to the south was made with these preserved materials and their sites on the



Text-fig. 1. Environmental factors during the period of experiment. 1, surface; 2, 2m deep; 3, 4m deep; 4, 6m deep.

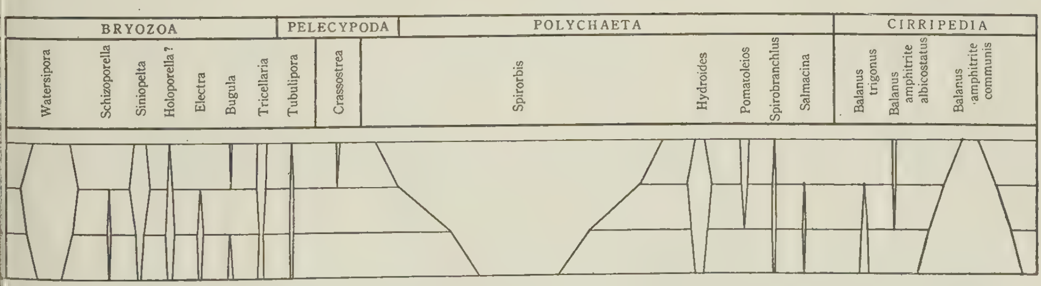
blocks, their shape and size were diagrammatically reproduced on a map (Text-figs. 5 and 6).

The test blocks were soaked in the water 10 m deep at a place 30 m south of Tatoku Marine Station. Water temperature, chlorinity and concentration of dissolved oxygen were 27.1°C, 15.67‰, 4.80 cc/L on the surface level, 26.1°C, 17.76‰, 4.41 cc/L at the depth of 2 m, 24.1°C, 18.36‰, 4.45 cc/L at 4 m and 23.7C°, 18.57‰, 4.26 cc/L at 6 m (Text-fig. 1). These represent the averages of the values obtained by the observations made on 8, 16, 22 and 29 July and 5 and 12 August, at about two o'clock p. m. in each.

II. Vertical distribution of species

Seventeen species of animals discovered on the test blocks within the confine of the examined area are listed together with their frequencies in Table 1. The first step to the disclosure of vertical distribution of respective species is counting the number of individuals (or colonies, if necessary) and finding the total from three blocks lying on the same level. The distribution may be told by the comparison of the resultant sums calculated for four different depths.

A mere comparison of them, however, does not necessarily convey the actual state of the specific difference, for a community is not established on a line, but on a plane. More reasonable way appears, in the authors' mind, to lie in an adaptation of "Kugelkurvenmethode" (LOHMANN, 1908) to the use in a



Text-fig. 2. Abundance of animals. Widths correspond to the diameter of the circles area of which represent the number; 1, 0.5 m deep; 2, 2 m deep; 3, 3.5 m deep; 4, 5 m deep.

Table 1. Number found within the area of 20 cm×20 cm. S, total; $\bar{x}$, mean. I, II, smooth surface; III, rough surface. $\sqrt{S}$, value representing relative length of abscissa in Text-fig. 2.

	Depth of 0.5 m						Depth of 2.0 m						Depth of 3.5 m						Depth of 5.0 m						Total
	I	II	III	S	$\bar{x}$	$\sqrt{S}$	I	II	III	S	$\bar{x}$	$\sqrt{S}$	I	II	III	S	$\bar{x}$	$\sqrt{S}$	I	II	III	S	$\bar{x}$	$\sqrt{S}$	
BRYOZOA																									
1. *Electra angulata*	0	0	0	0	0.0	—	0	0	0	0	0.0	—	1	4	0	5	1.7	2.24	0	1	0	1	0.3	1.00	6
2. *Tricellaria occidentalis*	2	6	11	19	6.3	4.36	7	15	5	27	9.0	5.20	0	6	1	7	2.3	2.65	3	4	1	8	2.7	2.83	61
3. *Bugula neritina*	0	0	1	1	0.3	1.00	0	0	0	0	0.0	—	0	0	0	0	0.0	—	2	3	5	10	3.3	3.16	11
4. *Schizoporella unicornis*	0	0	0	0	0.0	—	0	0	0	0	0.0	—	1	0	0	1	0.3	1.00	0	0	0	0	0.0	—	1
5. *Watersipora cucullata*	90	102	216	408	136.0	20.20	222	234	450	906	302.0	30.10	127	158	313	598	199.3	24.45	29	53	87	169	56.3	13.00	2,081
6. *Holoporella sp.?*	0	0	0	0	0.0	—	2	1	5	8	2.7	2.83	8	14	1	23	7.7	4.80	0	5	2	7	2.3	2.65	38
7. *Siniopelta costazii*	20	2	10	32	10.7	5.66	57	48	12	117	39.0	10.82	8	12	2	22	7.3	4.70	1	6	0	7	2.3	2.65	178
8. *Tubulipora pulchra?*	0	0	0	0	0.0	—	1	1	0	2	0.7	1.41	1	2	2	5	1.7	2.24	0	1	0	1	0.3	1.00	8
PELECYPODA																									
9. *Crassostrea gigas*	1	0	+0	1	0.3	1.00	0	0	0	0	0.0	—	0	0	0	0	0.0	—	0	0	0	0	0.0	—	1
POLYCHAETA																									
10. *Spirorbis foraminosus*	5,128	6,783	9,708	21,619	7,206.3	147.04	4,255	3,856	6,326	14,440	8,413.3	120.17	933	1,254	2,956	5,146	1,715.3	71.74	271	586	584	1,441	480.3	37.96	42,646
11. *Hydroides norvegica*	7	10	13	30	10.0	5.48	30	25	82	137	45.7	11.70	10	18	74	102	23.0	10.10	3	9	5	17	5.7	4.12	286
12. *Spirobranchus giganteus*	0	0	0	0	0.0	—	0	0	2	2	0.7	1.41	0	0	3	3	1.0	1.73	1	0	1	2	0.7	1.41	7
13. *Pomatoleios crosslandi*	2	5	22	29	9.7	5.39	3	6	1	10	3.3	3.16	0	0	0	0	0.0	—	0	0	0	0	0.0	—	39
14. *Salmacina dysteri*	0	0	0	0	0.0	—	0	0	0	0	0.0	—	0	0	3	3	1.0	1.73	0	0	0	0	0.0	—	3
CIRRIPEDIA																									
15. *Balanus trigonus*	0	0	0	0	0.0	—	0	0	0	0	0.0	—	1	2	5	8	2.7	2.83	5	7	6	18	6.0	4.24	26
16. *Balanus amphitrite albicostatus*	1	1	1	3	1.0	1.73	1	0	0	1	0.3	1.00	0	0	0	0	0.0	—	0	0	0	0	0.0	—	4
17. *Balanus amphitrite communis*	6	10	35	51	17.0	7.14	207	285	198	690	230.0	26.27	688	624	443	1,755	585.0	41.90	1,048	902	862	2,812	937.3	52.03	5,308
Total	5,257	6,919	10,017	22,193			4,785	4,474	7,081	16,340			1,778	2,094	3,806	7,678			1,363	1,577	1,553	4,493			50,704

Table 2. Results of the analysis of variance made for Table 1. d. f., degrees of freedom; s. s., sum of squares; v., variance; v. r., variance ratio. *, significant; **, highly significant.

	d. f.	*Watersipora cucullata*			*Siniopelta costazii*			*Holoporella sp.?*			*Tricellaria occidentalis*			*Spirorbis foraminosus*			*Hydroides norvegica*			*Pomatoleios crosslandi*			*Balanus amphitrite communis*		
		s. s.	v.	v. r.	s. s.	v.	v. r	s. s.	v.	v. r.	s. s.	v.	v. r.	s. s.	v.	v. r.	s. s.	v.	v. r.	s. s.	v.	v. r.	s. s.	v.	v. r.
Total	11	161,101			3,810			200			213			99,967,475			6,768			474			1,530,655		
Depth	3	96,942	32,314	17.07**	2,442	814	5.69*	94	31.3	2.20	91	30.3	2.42	83,264,227	27,754,742	30.39**	3,307	1,102	5.89*	228	76	2.81	1,474,118	391,372	68.18**
Set	2	52,767	26,384	13.96**	509	254	1.78	21	10.5	0.73	47	23.5	1.88	11,223,736	5,611,868	6.15*	2,341	1,170	6.26*	84	42	1.55	22,116	11,058	1.93
Error	6	11,392	1,899		859	143		85	14.2		75	12.5		5,479,512	913,252		1,120	187		162	27		34,421	5.737	

Table 5. Constitution of communities represented by percentage of the number to the total (confidence range 90%). bl., block form; en., encrusting form; er., erecting form. ◎, voluminous or tall.

Depth of 0.5 m

	% excluding *Spirorbis* / including *Spirorbis*	Life forms bl.	en.	er.
1. *Spirorbis foraminosus*	— / 97.4±0.2	○		
2. *Watersipora cucullata*	71.1±3.1 / 1.9±0.2		○	
3. *Balanus amphitrite communis*	8.9±2.0 / 0.2	◎		
4. *Siniopelta costazii*	5.6±1.6 / 0.2	◎		
5. *Hydroides norvegica*	5.2±1.6 / 0.1	○		
6. *Pomatoleios crosslandi*	5.0±1.5 / 0.1	○		
7. *Tricellaria occidentalis*	3.3±1.2 / 0.1			◎
8. *Balanus amphitrite albicostatus*	0.5 / +	◎		
the rest	0.4 / 0.0			
Total excluding *Spirorbis*		[illegible]	[illegible]	[illegible]

Depth of 2.0 m

	% excluding *Spirorbis* / including *Spirorbis*	Life forms bl.	en.	er.
1. *Spirorbis foraminosus*	— / 88.5±0.4	○		
2. *Watersipora cucullata*	47.7±2.0 / 5.5±0.3		○	
3. *Balanus amphitrite communis*	36.3±1.8 / 4.2±0.2	◎		
4. *Hydroides norvegica*	7.2±1.0 / 0.8±0.1	○		
5. *Siniopelta costazii*	6.2±0.9 / 0.7±0.1	◎		
6. *Tricellaria occidentalis*	1.4±0.5 / 0.2			◎
7. *Pomatoleios crosslandi*	0.5±0.4 / 0.1	○		
8. *Holoporella sp.?*	0.4 / +		○	
the rest	0.3 / 0.0			
Total excluding *Spirorbis*		[illegible]	48.1	1.4

Depth of 3.5 m

	% excluding *Spirorbis* / including *Spirorbis*	Life forms bl.	en.	er.
1. *Spirorbis foraminosus*	— / 67.0±0.9	○		
2. *Balanus amphitrite communis*	69.4±1.5 / 23.0±0.8	◎		
3. *Watersipora cucullata*	23.6±1.4 / 7.7±0.5		○	
4. *Hydroides norvegica*	4.0±0.6 / 1.3±0.3	○		
5. *Holoporella sp.?*	0.9±0.3 / 0.3		○	
6. *Siniopelta costazii*	0.9±0.3 / 0.3	◎		
7. *Balanus trigonus*	0.3 / 0.1	◎		
8. *Tricellaria occidentalis*	0.3 / 0.1			◎
the rest	0.6 / 0.2			
Total excluding *Spirorbis*		74.6	24.5	0.3

Depth of 5.0 m

	% excluding *Spirorbis* / including *Spirorbis*	Life forms bl.	en.	er.
1. *Balanus amphitrite communis*	92.2±0.7 / 62.6±1.2	◎		
2. *Spirorbis foraminosus*	— / 32.1±1.2	○		
3. *Watersipora cucullata*	5.5±0.7 / 3.7±0.5		○	
4. *Balanus trigonus*	0.6±0.3 / 0.4±0.2	◎		
5. *Hydroides norvegica*	0.6±0.3 / 0.4	○		
6. *Bugula neritina*	0.3 / 0.2			◎
7. *Tricellaria occidentalis*	0.3 / 0.2			◎
8. *Holoporella sp.?*	0.3 / 0.2		○	
the rest	0.2 / 0.2			
Total excluding *Spirorbis*		93.4	5.8	0.6

plane. This consists in representing the number of animals as the area of a circle, the diameter of which provides the adequate base for the comparison. Table 1 shows the result of the calculation (Text-fig. 2).

In confirmation of whether or not the distributional differences according to the depths are statistically significant, the so-called analysis of variance was applied to the results inserted above (Table 2). The analysis revealed that the differences are significant in *Siniopelta costazii* and *Hydroides norvegica* and more highly so in *Watersipora cucullata*, *Spirorbis foraminosus* as well as in *Balanus amphitrite communis*. Distribution of each of these five species was examined further in detail on the basis of the percentage of the number found on three blocks lying on the same level to the total of all twelve blocks (Table 3).

Table 3. Percentage of animals found at each of four levels to the total (confidence range 90%).

Species \ Depth	0.5 m	2.0 m	3.5 m	5.0 m	Total (%)
Watersipora cucullata	19.6±1.5	43.5±1.8	28.8±1.6	8.1±1.0	100.0
Siniopelta costazii	18.0±4.8	65.7±5.9	12.4±4.0	3.9±2.5	100.0
Spirorbis foraminosus	50.8±0.4	33.9±0.4	12.0±0.3	3.3±0.1	100.0
Hydroides norvegica	10.5±3.0	47.9±4.9	35.7±4.6	5.9±2.2	100.0
Balanus amphitrite communis	1.0±0.2	13.0±0.7	33.0±1.1	53.0±1.1	100.0

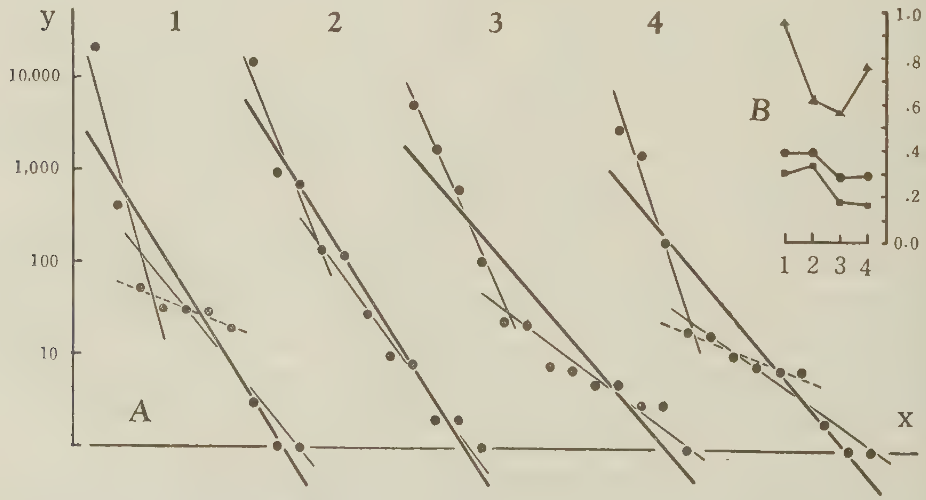
Spirorbis, attaining to 50.8% at the uppermost level, is decreased to 33.9% at the next level, to 12.0% at the third level and to 3.3% at the lowest level. In *Balanus amphitrite communis* the tendency of distribution is completely reversed, for the percentage increases successively from above downward from 1.0% to 13.0%, 33.0% and 53.0%. Despite a distinct decrease at the first level, *Watersipora* more or less resembles *Spirorbis* in its distribution. Percentage largest at the second level reaches 43.5%, whereas that of the first level is reduced to 19.6% and at the other two levels it is 28.8 and 8.1%. A similar inclination is perceptible also from *Hydroides* and *Siniopelta*.

Whether or not the differences observable among three sets of blocks are significant was also tested by the same analysis. The difference are significant in *Spirorbis* and *Hydroides* and highly so in *Watersipora*, but those in *Siniopelta* and *Balanus*, on the contrary, are insignificant in spite of that the vertical variances are significant. Unequalness among the sets may be ascribable to the qualitative dissimilarity between the smooth and the rough faces of the blocks.

III. Constitution of communities

Although the constitutional aspects of the communities at four different depths are to some extent perceptible from Text-fig. 2, numerical composition of species is more feasible for the comparison of their characteristics.

For each of the communities at four different depths, individual number (or colonial) of respective species was represented by the percentage to the total of all the species (Table 5). Occupying 10% or more of the occurring animals in most of the cases, *Balanus amphitrite communis* and *Spirorbis* are dominant over all others. A matter interesting to us is that these two are completely reversed in their inclination in the change of rate of their appearance with the depths. *Balanus* which is so scarce as to reach but 0.2% in the highest layer increases to 4.2% in the second layer, to 23.0% in the third and to 62.6% in the lowest. *Spirorbis*, attaining to 97.4% in the uppermost layer, decreases successively to 88.5%, 67.0% and 32.1%. This animal, however, occupies a peculiar situation in the community, for it remains very small in size even in the adult, in spite of its great abundance. If *Spirorbis* is left out of account, *Watersipora* is the most abundant in the highest layer, where the latter occupies 71.1% of all the animals other than the former. The latter decreases with the increase of depth as the former does, the percentage changing from 47.7% in the second layer downward to 23.6% and to 5.5%. Contradictory inclination between *Spirorbis* and *Balanus* in their transition of frequencies with the depths holds true between the latter and *Watersipora* in the case of excluding the former. *Balanus*, occupying 8.9% of all the animals exclusive of *Spirorbis* at the first level, rises to 36.3% at the second and to 69.4% at the third, at which it exceeds *Watersipora* in its rate. At the fourth level, the disparity proceeding further between them, *Balanus* is increased as much as 92.2% in contrast to the reduction of *Watersipora* to 5.5%.



Text-fig. 3. A: Regression lines showing the relation between the number of individuals and the rank of species. x, rank of species; y, number of individuals or colonies. B: Value of a in the line, $log\ y+ax=b$. Circle, the case inclusive of all species; triangle, dominant group; square, subordinate group. 1, 2, 3, 4, as in Text-fig. 2.

MOTOMURA (1932) holds that in a community which makes its development in a more or less confined area a rough relation that $\log y + ax = b$ exists, where x represents the ordinal of the rank which the species in question takes in the arrangement of all in due order of their abundance, y the number of individuals, a and b the constants. He points out, further, that if this line of regression is really legitimate, it may be facilitated by the comparison of the values of a to know the complexity or the simplicity of the constitutions of communities. Values of a computed following his method with respect to the species appearing in the present experiment are listed in Table 4. It may be seen from this that there is a jump in the values observable in the second and third levels (Text-fig. 3). As they are larger in the upper two levels than in the lower two, it naturally follows that the communities are simpler in constitution in the former than in the latter.

Table 4. Numerical value of a in $\log y + ax = b$.

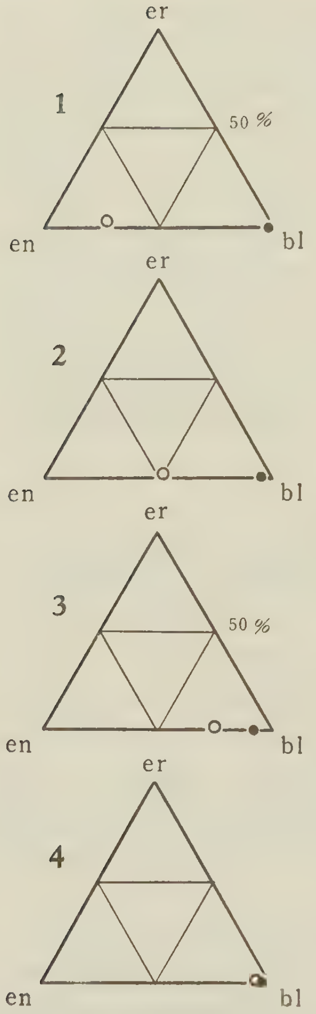
Depth	For all species	For group most frequent	For group least frequent	For group moderately frequent
0.5 m	0.389	0.942	0.301	0.090
2.0 m	0.389	0.618	0.325	——
3.5 m	0.282	0.556	0.177	——
5.0 m	0.291	0.750	0.169	0.094

In so far as, however, the points plotted in Text-fig. 3 deviate too much from the regression lines to be regarded as linearly arranged, the conclusion deduced above can not be justified in a strict sense and does not go beyond a simple suggestion of general tendency.

The regression lines tentatively and separately drawn for groups, one comprising only four dominant species and the other the rest, fit in better with the points plotted by their describing an L together. This appears to show that the interspecific correlations which may exist among the constituent animals of community are not of simple nature and to point to the adequacy of treating the problem separately for superior and inferior groups. In the uppermost layer, it happens that an intermediate group with the value of a 0.09 is recognizable. Regression lines drawn for those three groups make an S shape in all. The lowermost layer also shows a similar tendency.

IV. Advanced stage of communities with special reference to the growth and life form of animals

Fouling communities composed of various groups of animals comprise naturally various kinds of life forms, which take step by step more distinct figures with the growth. As the principal forms, we can enumerate block, encrusting



Text-fig. 4. Triangular co-ordinates showing the character of communities. en, encrusting form; bl, block form; er, erecting form. Black circle, the case including *Spirorbis*; white circle, the case excluding *Spirorbis*. 1, 2, 3, 4, as in Text-fig. 2.

and erecting ones. The animals appearing on the test blocks can be designated to one of these.

1. Block forms:—*Balanus*, *Crassostrea*, *Siniopelta* (voluminous); *Hydroides*, *Pomatoleios*, *Spirorbis* (less voluminous).

2. Encrusting forms:—*Watersipora*, *Schizoporella*, *Electra*, *Holoporella*.

3. Erecting forms:—*Tricellaria*, *Bugula* (tall and massive).

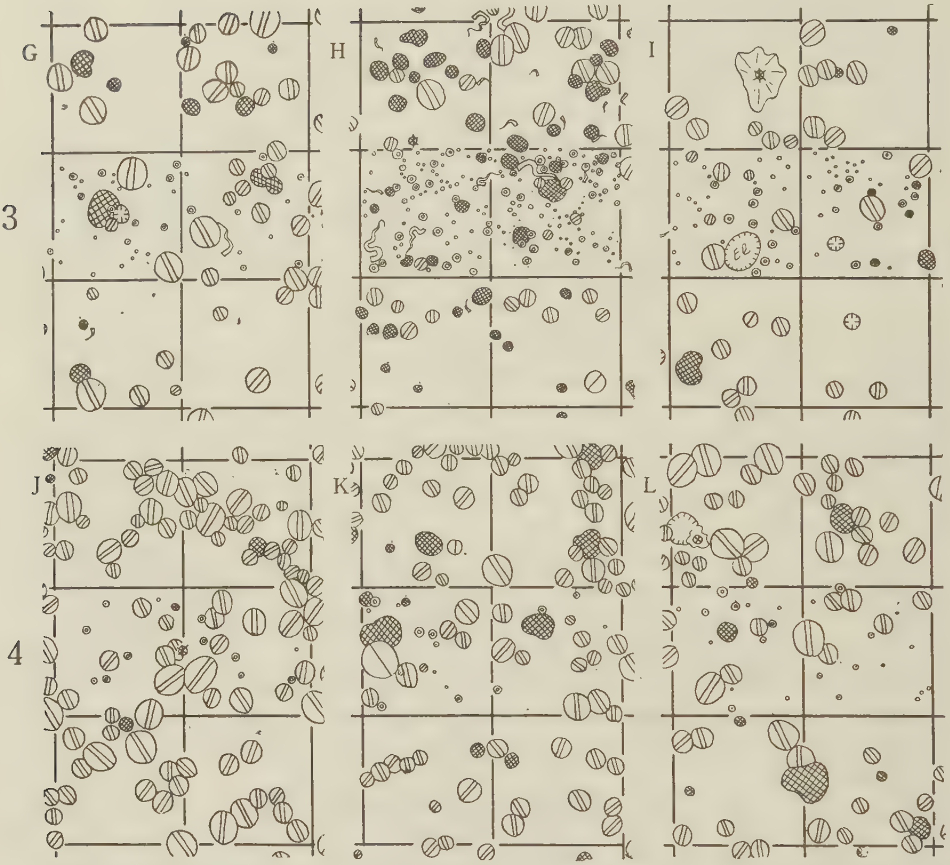
For each of the life forms and for each of the levels, the percentage of the number of animals to the total was calculated (Table 5). In case *Spirorbis* is included, the appearance of community deserves the name of block one at all four depths. At the first and second levels, the community chiefly composed of *Spirorbis* can be assigned to the block form, but less voluminous. At the other levels it is called by the same name, but its principal constituent, *Balanus amphitrite communis* is more voluminous. When *Spirorbis* is excluded, the community ought to be regarded as encrusting form at the first level, encrusting, or less voluminous block one at the second, more voluminous block one at the third and the most voluminous block one at the fourth (Text-fig. 4). The encrusting form is represented by *Watersipora* and *Holoporella*? and the block form by the majority of others. *Bugula* and *Tricellaria* can be reckoned among the erecting forms, but their colonies are rather scarce in number.

As to the constitution of communities, those developing at the first level are chiefly composed of *Spirorbis* which occupies 97.4% of the whole (Text-fig. 5 and also refer to Table 5). Somewhat less conspicuous existence is *Watersipora* which remains merely in 1.9%. One can name, further, *Balanus amphitrite communis* (0.2%), *Siniopelta* (0.2%) and *Hydroides* (0.1%), each of which does not exceed 1%. At the second level, *Spirorbis* is decreased to 88.5% in contrast to the increase of *Watersipora* and *Balanus* which attain to 5.5 and 4.2% respectively. *Hydroides* (0.8%), *Siniopelta* (0.7%), *Tricellaria* (0.2%) and *Pomatoleios* (0.1%) join the community as less

Text-fig. 5. Diagramatic representation of actual community in the area of 5cm×7.5cm in the middle of block surface. *Spirorbis* is shown confined to narrower area of 5cm×2.5cm. A, C, D, F, smooth surface; B, E, rough surface. 1, 2, as in Text-fig. 2. a, *Electra angulata*; b, *Tricellaria occidentalis*; c, *Bugula neritina*; d, *Schizoporella unicornis*; e, *Watersipora cucullata*; f, *Holoporella sp.*?; g, *Siniopelta costazii*; h, *Spirorbis foraminosus*; i, *Hydroides norvegica*; j, *Pomatoleios crosslandi*; k, *Balanus trigonus*; l, *Balanus amphitrite communis*.

important representatives. Except *Watersipora* which shows a certain growth, almost all others are retarded in development. Since *Spirorbis* differs from others very little in its body size, its presence can not be negrected in the calculation.

At the third level, *Spirorbis* is diminished in its percentage to 67.0% (Text-fig. 6). *Balanus* and *Watersipora* which rank among the major species attain each to 23.0% and to 7.7%. *Hydroides* (1.3%), *Siniopelta* (0.3%) and *Holoporella*? (0.3%) can also be named, though they belong to the minority. At the fourth level, *Spirorbis* lessened to 32.1% make a contrast with *Balanus* which rises to 62.6%. *Watersipora* still retains 3.7% though it is greatly



Text-fig. 6. Same. G, I, J, L, smooth surface; H, K, rough surface. 3, 4, as in Text-fig. 2.

reduced. Such minor members as *Balanus trigonus* (0.4%), *Hydroides* (0.4%), *Tricellaria* (0.2%) and *Bugula* (0.2%) may be added to the constituents. The communities at the lower two levels show a very conspicuous growth of *Balanus* and *Watersipora* in comparison with those at the upper two. Existence of *Spirorbis* is relatively inconspicuous, even though it is present in a large number, because it remains small in size in contrast to other animals growing large.

Those facts tell that the communites at the lower two levels are more advanced in their development than those at the upper two.

V. Consideration

Up till now, numbers of works have been published on the intertidal zonation of animals on the rocky beach (COLMAN, 1933; STEPHENSON and STEPHENSON, 1949; etc.) In them, the substrata were kept on the bottom and placed under the tidal influence unlike those of the present experiment in which they were always maintained at the definite depths. In consulting the past works, it must

be born in mind that the unequal methods naturally give rise to differential results.

Vertical distribution of species:—TOKUOKA (1940) stated that the abundant attachment of *Spirorbis* to the substratum takes place near the water surface as well as near the bottom. MAWATARI (1954) recorded a larger settlement at the depth of 1.5 m than at 3.0 m. The present study is in complete agreement with their results.

According to TOKUOKA (1940), the layer most abundant in *Hydroides*, which frequently inhabits in the middle layer is variable depending on the depth of the sea. In his study on the depth shallower than 8 m, MIYAKE (1940) showed that *Hydroides* most abundant in the layer of 3–4 m deep is less so near the surface and least at the depth of 5 m or more. EDMONDSON (1944) pointed out that the water surface in Hawaii abounds in this species more than other regions does. The present experiment has yielded a similar results as MIYAKE's, though the most abundant layer lies 1 m higher.

TOKUOKA (1939) noted that *Watersipora* is more plentifully found near the bottom, whereas MIYAKE (1940) spoke of it as occurring in a quantity at the depth of 3 m or less and disappearing from the range of 4 m to 8 m. McDOUGALL (1943) found greater occurrence of *Schizoporella unicornis*, a near ally of *Watersipora*, within the limit of 1 foot above the bottom. The present result agrees with MIYAKE's, in that the species abounds in shallower water, but a disagreement lies in that a decrease is again perceptible in the region near the surface.

Balanus amphitrite communis is noticed by TOKUOKA (1939) as showing two maxima, one at the middle level and the other near the bottom. These are almost equal in quantity, or one slightly exceeds the other. The present experiment is in accord with his in that the attachment of the species rises with the depth, at least within the range of 5 m.

Communities at various depths:—So far as the present authors are aware, little has been known about the constitutional differences among the fouling communities from various depths. VISSCHER (1927), in his studies on the growths on the ships' bottom, which bears a certain connection with the problem before us, took notice of the presence of three distinct zones, the first, the "algal zone", extending from the water-line to a depth of 3 feet and containing *Enteromorpha*, *Balanus* spp. and others, the second fouled by a scattered growth of barnacles and encrusting bryozoans and the third composed of abundant hydroids, besides scattering mussels, ascidians and barnacles. PYEFINCH (1950), who recognized the well-known zonal settlement of algae near the water-line, stated that a closer examination does not suggest the restriction of any of the animals to a particular level.

The present study reveals the presence of two distinct zones. The upper

zone dominated by *Spirorbis* and *Watersipora* abounds in number, but not in species, and the development of the community remains in a comparatively early stage (Text-fig. 5). The lower zone mainly composed of *Balanus* is short of number but enriched with species, which are rather advanced in growth (Text-fig. 6). No "algal zone" is found, for the experiment was made out of season. Other discrepancies between the observation on the hull and the present study originate in the difference of methods.

Regression lines showing the relation between the number of individuals and the rank of species:—Admitting the gradual alteration of forms of regression lines in the community of terrestrial weeds during the course of development, NUMATA (1956) declared that those which are first straight make a change with time into L, and finally into S. Roughly speaking, the regression line obtained from the present observation is straight only for the second level, but of L shape for the third and of S shape for tne first and fourth. Inasmuch as the development of communities is more advanced in lower layers, it may be natural that the alteration of the form with the depths agrees with his statement. But it is incomprehensible why it takes S shape in the first layer. What does this peculiarity imply is still uncertain and this demands further studies.

Life forms and growth:—As mentioned before, constitution of fouling communities can not be disclosed merely on the basis of the number of individuals (or colonies). In an advanced community, the shape and volume of animals have an intimate connection with its nature. It has already been pointed out that, in considering the nature of communities from the third and fourth levels, *Spirorbis* ought to be left out of account, for their advanced development reduces this animal to rather inconspicuous existence. If one admits that principle, the communities at four different depths four weeks after their establishment are: less voluminous block form community of the first level composed of *Spirorbis* and *Watersipora*, the same one of the second level, but with the addition of *Balanus*, voluminous block form of the third level comprising *Balanus*, *Watersipora* and *Hydroides* and the same one of the fourth level, but without the last animal. Undergoing further development, the communities of the upper two levels may soon be reduced in *Spirorbis*, and the result is the yield of encrusting form community of *Watersipora* and a similar one of *Watersipora* and *Balanus*.

Environmental factors:—It may appear to be unique that deeper communities are more advanced in their development than shallower one are. As regards the environmental factors which may exert an effect upon the development (Text-fig. 1), high concentration of chlorinity, or relatively low water temperature may be considered. There is no need of taking the paucity of dissolved oxygen into account, for it is obvious that this arrests the development.

Difference in chlorinity between the second and third levels is too small as compared with that between the former and the first level. It is hardly explicable with this disparity of chlorinity, that the development is more advanced at the lower levels than at the upper. Accordingly, the differences of growth may be ascribable to the water temperature, which is too high in the upper levels to be favorable for the animals.

Résumé

1) Communities fouling the concrete blocks immersed at the depths of 0.5 m, 2.0 m, 3.5 m and 5.0 m at Tatoku in Ago Bay for four weeks ranging from July 10 to August 7, 1958 were studied.

2) Vertical distribution of species was demonstrated on the graphs by showing their number and the statistical significance was confirmed by the analysis of variance. These tell that the upper layer abounds in *Spirorbis foraminosus*, whereas the lower is rich in *Balanus amphitrite communis*. *Watersipora cucullata*, though abundant at upper levels, is somewhat less near the surface. *Hydroides norvegica* and *Siniopelta costazii* show a similar tendency.

3) Dominant animals in the communities at four different depths are as follows: first level: *Spirorbis* and *Watersipora*; second level: *Spirorbis*, *Watersipora* and *Balanus*; third level: *Spirorbis*, *Balanus* and *Watersipora*; and fourth level: *Balanus*, *Spirorbis* and *Watersipora*.

4) The upper layer abounds in number, but not in species, whereas the lower is short of number though enriched with species.

5) The regression lines calculated on the basis of the rank of abundance of respective species and their number of individuals (or colonies) reveal that the communities are simpler in composition at the upper two levels than at the lower two.

6) Communities from the upper two levels are comparatively arrested in their development and those from the lower two somewhat more advanced. In an advanced stage, *Spirorbis* became less conspicuous owing to the growth of others. Appropriate comparison may be drawn by including *Spirorbis* in the upper two levels but by excluding it in the lower two.

7) Based on the life form, communities after the lapse of four weeks may be classified into less voluminous block ones of the upper two levels and voluminous block ones of the lower two. It is conjectured that with further development those of the former soon become the encrusting ones composed of *Watersipora*.

8) Accelerated development in the communities of the lower levels is attributable to the temperature nearly optimum for growth.

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Taxonomical Consideration on the Fishes referable to the Genus *Chlorophthalmus*

(*With Text-figs. 1–7, Tables 1–4*)

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1. Introduction

The fishes belonging to the genus *Chlorophthalmus* are distributed in a rather deep area in neighborhood of the continental shelf, the depth of which ranges over 100 m. to 500 m.. Especially, *Chlorophthalmus albatrossis* JORDAN and STARKS and *C. acutifrons* HIYAMA are the important fishes for the deep-sea drag-net fishery which is operated during the period extending from September to May in the following year in Kumano-Nada, Mie Prefecture, Japan.

Although the taxonomy of this group has been detected by C. T. REGAN (1911), A. E. PARR (1928), T. R. NORMAN (1931), M. YAMAGUCHI (1941), and T. KAMOHARA (1956), its details have remained incomplete and unsatisfactory up to the present day. Especially, the osteological features of this group has not been clarified by any ichthyologists.

In the present study,* the authors attempted the comparative studies of the external and internal features of this genus to define the relationships of each species satisfactorily.

The materials used in the present study are 98 individuals, preserved in 10 per cent of formalin after collection. Date of collection and locality on the distinction of each species are indicated in Table 1.

Table 1. Showing meterials on the distinction of each species.

Scientific name	Japanese name	Locality	Date	Range of standard length	No. of individuals
Chlorophthalmus albatrossis J. & S.	Aome-eso	Owashi	1951. 9. 21. 1953. 3. 27. 1958. 1. 30.	57.0–138.0mm	38
Chlorophthalmus acutifrons HIYAMA	Tomomehikari	Owashi	1951. 9. 21. 1953. 3. 27. 1958. 1. 30.	95.0–182.0mm	39
Chlorophthalmus oblongus KAMOHARA	Tsumaguro-aome-eso	Owashi	1957. 3. 20. 1958. 1. 30.	64.0– 98.8mm	15
Chlorophthalmus oblongus KAMOHARA	Naga-aomeeso	Owashi	1957. 3. 20.	61.5– 69.0mm	6

* The authors appreciate with the help of Mr. KIYOSHI SUZUKI in various ways.

II External feature

Chlorophthalmus oblongus is clearly distinguishable from the other species in general appearance. Namely, in this species the body is cylindrical in form and the adipose fin is much reduced in size, but in the others the body is moderately compressed and the adipose fin is well developed. Furthermore, the conspicuous differences of the external features among the species are concretely shown in Table 2.

C. albatrossis:

The head is 24.9–28.7% into body length and shorter than those of the other three species. The diameter of eye is longer than the snout length. Height of the dorsal fin is 70.4–76.9% into head and higher than those of *C. acutifrons* and *C. nigromarginatus*. Width of the interorbital space is 70.4–76.7% into

Table 2. Showing the count and measurement of meristic and proportional features in four species of *Chlorophthalmus*.
C, *Chlorophthalmus*; *alba*, *albatrossis*; *acut*, *acutifrons*; *nigr*, *nigromarginatus*; *oblo*, *oblongus*; B, Body; L, Length; Dist, Distance; No, Number;

Items \ Species	*C. alba.*	*C. acut.*	*C. nigr.*	*C. oblo.*
Hear into B. L.	24.9-28.7	28.8-32.5	29.4-32.3	25.6-31.3
Height into B. L.	17.5-21.2	18.9-22.7	17.2-20.7	13.4-20.1
Width into B. L.	13.4-16.7	12.6-15.8	12.7-16.2	13.9-21.5
Dist. between tip of snout and origin of dorsal into B. L.	35.3-40.4	36.5-40.1	37.2-41.7	36.6-42.7
Dist. between tip of snout and origin of ventral into B. L.	38.46-2.8	39.5-43.5	39.8-43.9	38.3-45.1
Dist. between tip of snount and origin of anals into B. L.	73.5-78.9	73.4-77.2	74.1-79.8	68.8-75.9
Dist. between tip of snout and anus into B. L.	45.4-49.8	48.6-53.2	48.1-52.6	47.7-56.3
Eye into head	36.2-39.2	24.8-29.7	29.7-35.9	33.5-41.4
Snout into head	26.5-30.3	31.8-35.6	29.4-33.7	24.3-32.1
Caudal peduncle (Depth) into head	27.2-32.8	25.7-30.4	26.6-30.9	20.5-29.6
Caudal peduncle (Length) into head	63.7-68.4	52.5-59.4	52.3-58.6	67.2-75.4
Maxillary into head	40.8-45.1	40.3-45.6	41.2-45.7	39.6-48.9
Pectoral into head	66.7-72.4	65.3-72.5	63.7-69.1	78.5-87.7
Dorsal (Height) into head	70.4-76.9	63.8-70.1	61.7-68.5	66.4-75.8
Ventral into head	61.4-66.5	60.2-65.6	57.6-63.4	62.1-69.8
Anal (Height) into head	35.9-42.2	40.2-46.7	35.6-41.3	28.4-37.8
Interorbital width into head	70.4-76.7	63.8-70.1	61.7-68.5	68.4-78.3
No. of pectoral rays	14-16	15-18	15-16	18-19
No. of dorsal rays	11	11	9-16	9
No. of ventral rays	9	9	9	9
No. of anal rays	9-10	8-10	8-9	8-9

head and wider than those of *C. acutifrons* and *C. nigromarginatus.*

C. acutifrons:

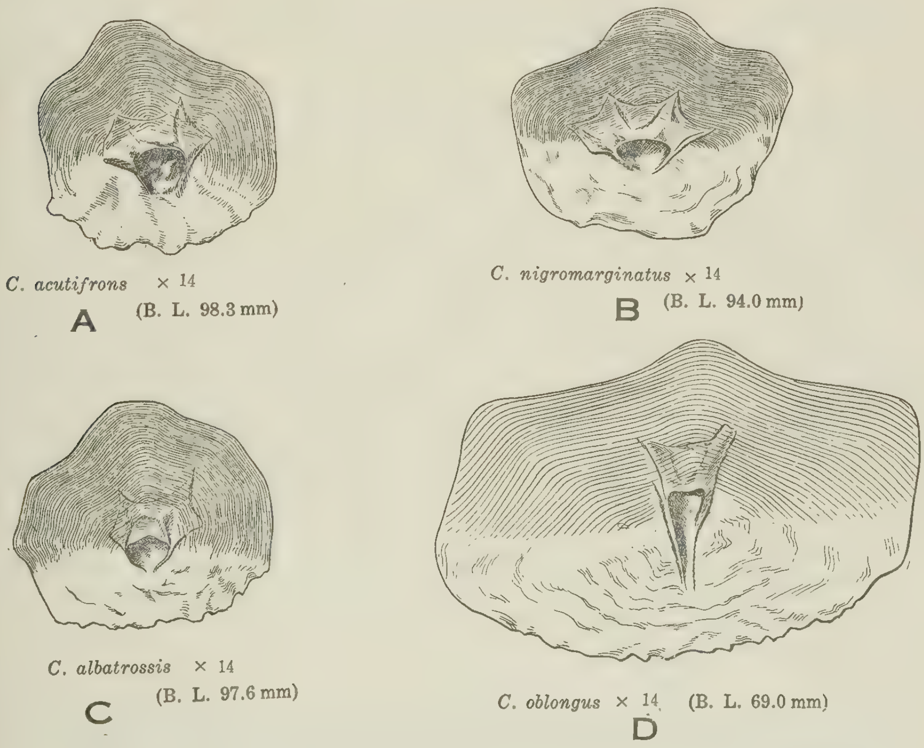
The snout length is longer than the diameter of eye. Length of the caudal peduncle is 52.5–59.4% into head and shorter than those of *C. albatrossis* and *C. oblongus*. Height of the anal fin is 40.2–46.7% into head and longer than those of the others.

C. nigromarginatus:

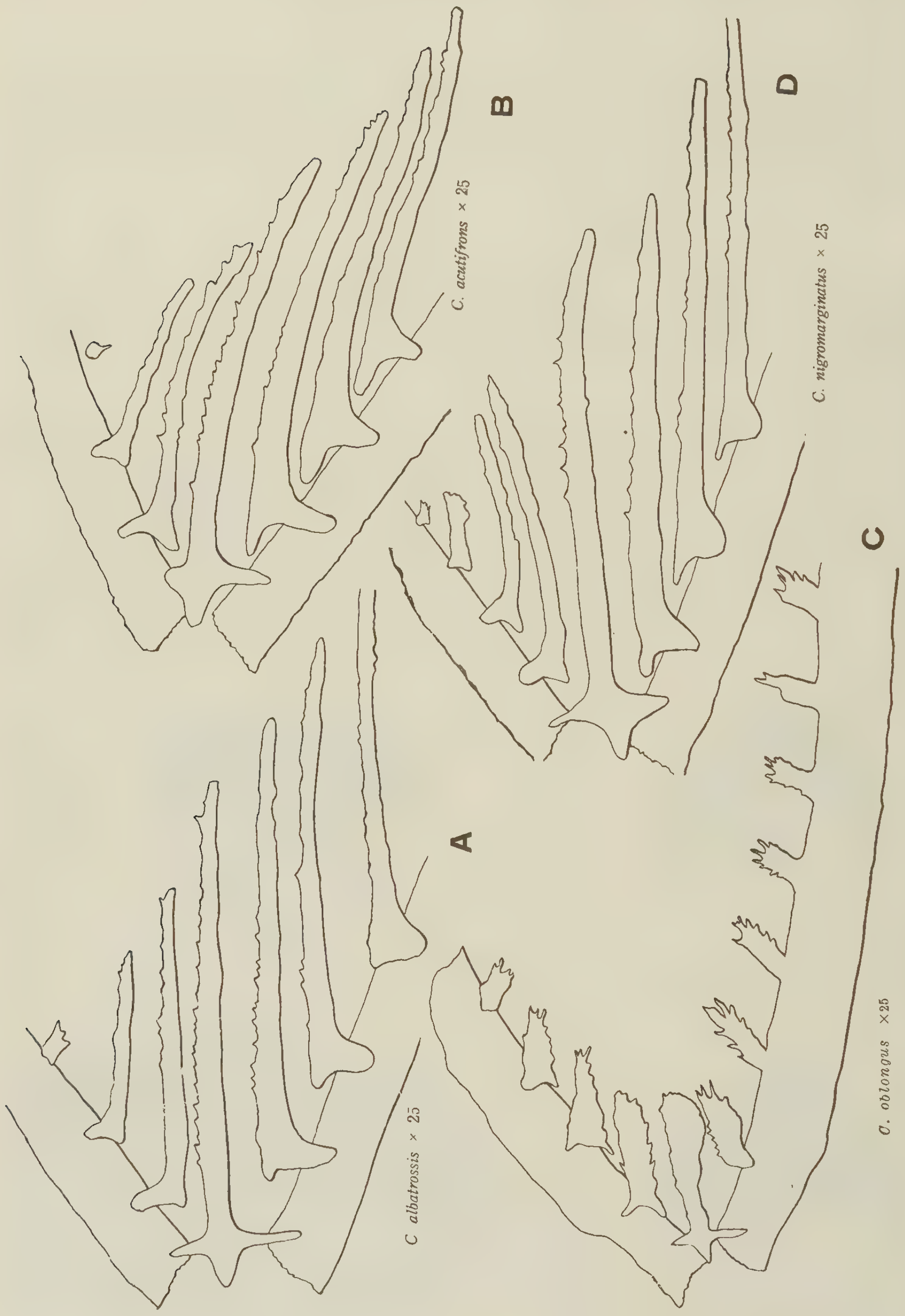
The snout length is about as long as the diameter of eye. Length of the caudal fin is 52.3–58.6% into head and about as long as the case in *C. acutifrons*. Length of the pectoral fin is 63.7–69.1% into head and slightly short among the four species.

C. oblongus:

The body height is 13.4–20.1% into body length and the lowest among the four species. The body width is 13.9–21.5% into body length and the widest among the four species. The diameter of eye is longer than the snout length. Length of the caudal peduncle is 67.2–75.4% into head and longer than those of the others. Length of the pectoral fin is 78.5–87.7% into head and longer than those of the others, and number of the pectoral rays is 18–19 and the most



Text-fig. 1. Scales of left lateral line in four species of the *Chlorophthalmus*.



Text-fig. 2. Gill raker on the left first arch in four species of the *Chlorophthalmus*.

numerous among the four species. Height of the anal fin is 28.4–37.8% into head and shorter than those of the others.

1. Scales in lateral line

Number of scales in lateral line is 55–59 in *C. albatrossis*, 52–58 in *C. acutifrons*, 52–55 in *C. nigromarginatus*, and 41–45 in *C. oblongus*.

C. oblongus can be clearly distinguished from the others in having the fewest number of scale in lateral line.

Furthermore, there are some differences in the structure of the scale in lateral line between *C. oblongus* and the others. In the *Chlorophthalmid* fishes, each scale in lateral line is respectively provided with the lateral organ in the centre. In *C. oblongus*, the structure of the lateral organ is a V-shape in form, but in the others, it is rather horseshoe-shaped. Each scale in lateral line is very large and rectangular in shape in *C. oblongus*. Otherwise, in the others, it is not so large as in *C. oblongus*, and circular in shape. (Text-fig. 1)

2. Gill raker

The number of gill rakers on the first arch of the four species are given in Table 3.

As indicated in the table, there are slight differences among the four species, but it is rather imcomplete and unsatisfactory to use the count for a distinct character.

In *C. oblongus*, the gill raker is much reduced in length, and somewhat wart-like in form, whereas in the others, it is much attenuated, and tapering gradually into a pointed tip. Moreover, each raker is unexceptionally armed with prickles which are small and numerous. In *C. oblongus*, they are closely set on the outer and inner sides of the raker, but in the others, only on the outer side. (Text-fig. 2)

Table 3. Showing the range and average of gill rakers in four species of *Chlorophthalmus*.

Items / Species	No. of individuals	Range			Average		
		Upper limb	Lower limb	Total	Upper limb	Lower limb	Total
C. acutifrons	39	3-4	13-15	17-19	3.9	14.2	18.1
C. albatrossis	38	3-5	14-18	18-22	4.0	15.9	19.8
C. nigromarginatus	15	4-6	13-16	18-22	5.1	15.1	20.7
C. oblongus	6	4-6	14-15	19-21	4.8	14.5	19.3

3. Jaws

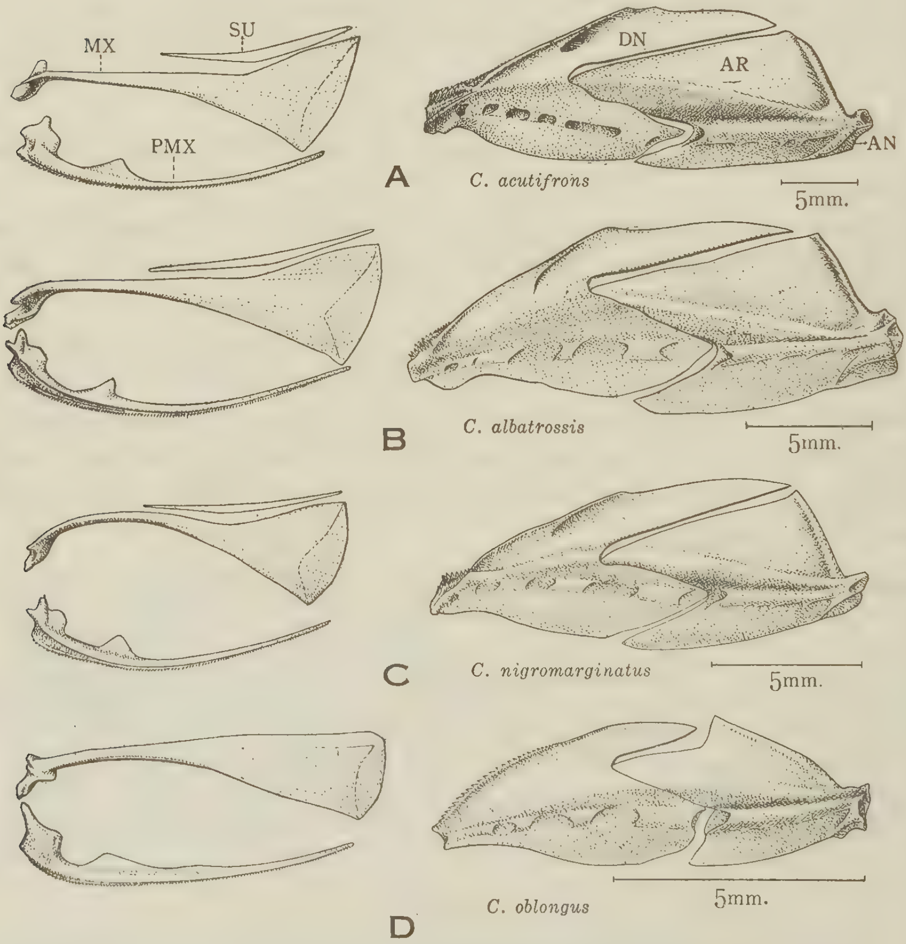
In the three species, with the exception of *C. oblongus*, the upper jaw is usually composed of three bones, the supramaxillary, maxillary, and premaxil-

lary. But, in *C. oblongus*, it is composed of two bones, the maxillary and premaxillary, and there is no supramaxillary on the upper margin of the maxillary.

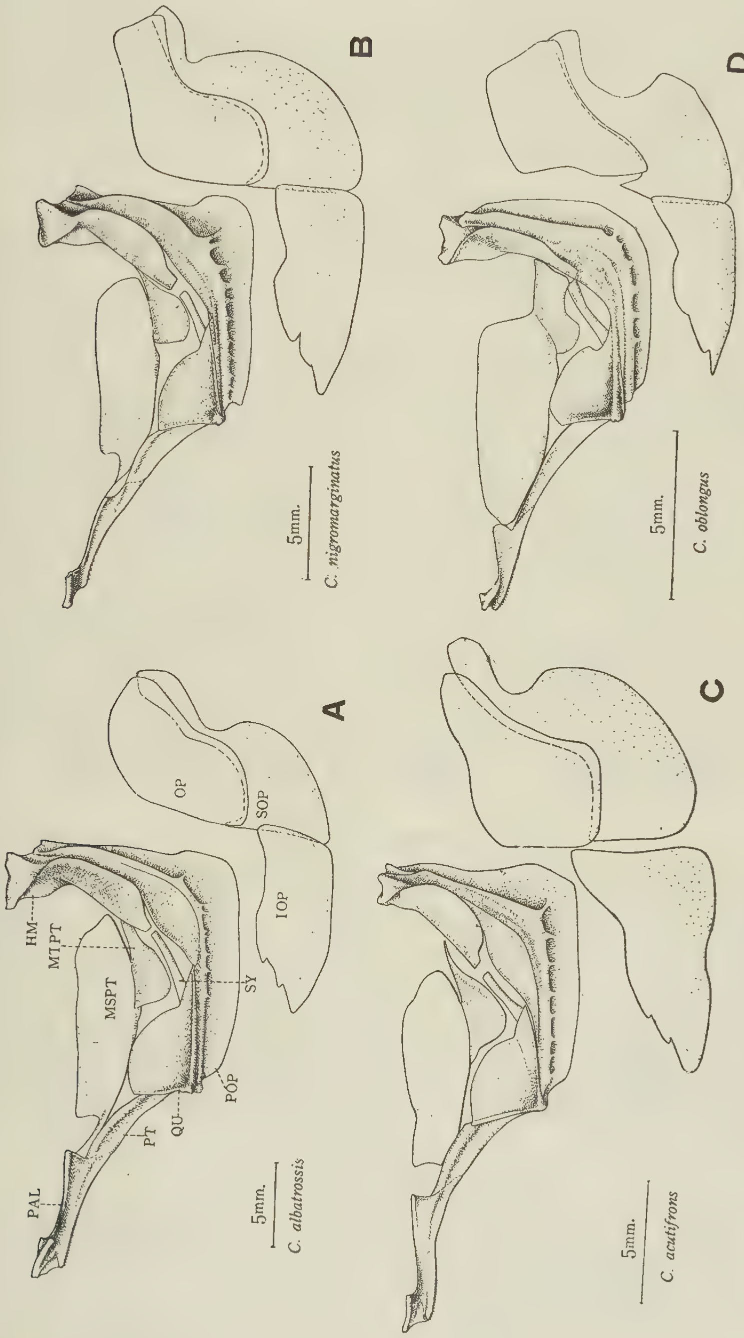
The lower jaw is unexceptionally composed of three bones, the dentary, articular and angular in four species. In *C. oblongus*, the minute teeth are closely set on the dorsal margin of the dentary. But, in the others, the small conical teeth are rather sparcely placed in two series and in a single series at the posterior part of the band. Moreover, in these species, the outer teeth are usually smaller than inner ones.

In *C. oblongus*, the extremity of dorsal arm of the dentary is roundish in lateral aspect, while in the others it gradually becomes to be slender and rather sharply projects backward.

The interosseous part of the dorsal branch of the dentary and the upper



Text-fiig. 3. Jaws of four species of the *Chlorophthalmus*. SU. supramaxillary; PMX, premaxillary; MX, maxillary; DN, dentary; AN, angular; AR, articular.



Text-fig. 4. Lateral view of the suspensorium and opercular apparatus in four species of the *Chlorophthalmus*. PAL, palatine; PT, pterygoid; QU, quadrate; MSPT, mesopterygoid; SY, symplectic; POP, preopercle; SOP, subopercle; OP, opercle; IOP, interopercle: HM, hyomandibular.

margin of articular is broadly opened in *C. oblongus*. But in the others the interosseous part is scarcely opened.

In *C. oblongus*, the upper margin of articular is rather concave, but in the others it is almost straight.

Thus, *C. oblongus* is clearly distinguished from the other three species in the above-mentioned features. (Text-fig. 3)

4. Suspensorium

The suspensorium is a party of bones that covers the side of the head. The palatine is situated on the anterior extremity of suspensorium. This bone is usually armed with the teeth on the ventral margin. The pterygoid is a bow-shaped bone, articulating with the palatine and the entopterygoid anteriorly, with the quadrate posteriorly. The quadrate is a flat triangular bone. At the lower end, it bears a condyle, articulating with the posterior end of the articular. The bone is joined partly with the symplectic. The metapterygoid is triangular bone, and the upper portion of this bone is articulating with the lower portion of the pterygoid. The hyomandibular is situated on the postero-upper part of the suspensorium.

The differences in the skeletal features of suspensorium are somewhat definitely found in the contours of the quadrate and metapterygoid. Namely, the dorsal margin of the quadrate is rather rugged, while in the others it is smooth; the inner surface of metapterygoid is partly armed with the conical teeth in *C. oblongus*, but it is not toothed in the others. (Text-fig. 4)

5. Opercular apparatus

The opercular apparatus consists of four bones, the preopercle, interopercle, subopercle and opercle. The preopercle is crescent in shape, situating on the anterior part of the apparatus. It articulates anteriorly with the quadrate and hyomandibular, and covers posteriorly the anterior parts of the opercle and subopercle and ventrally the upper part of the interopercle. In the dorsal surface of the bone, the sensory canal runs through the ventrical axis of the bone. The opercle is an echelon-shaped in *C. oblongus*, but it is a bottle-shaped in the others. (Text-fig. 4)

6. Shoulder girdle

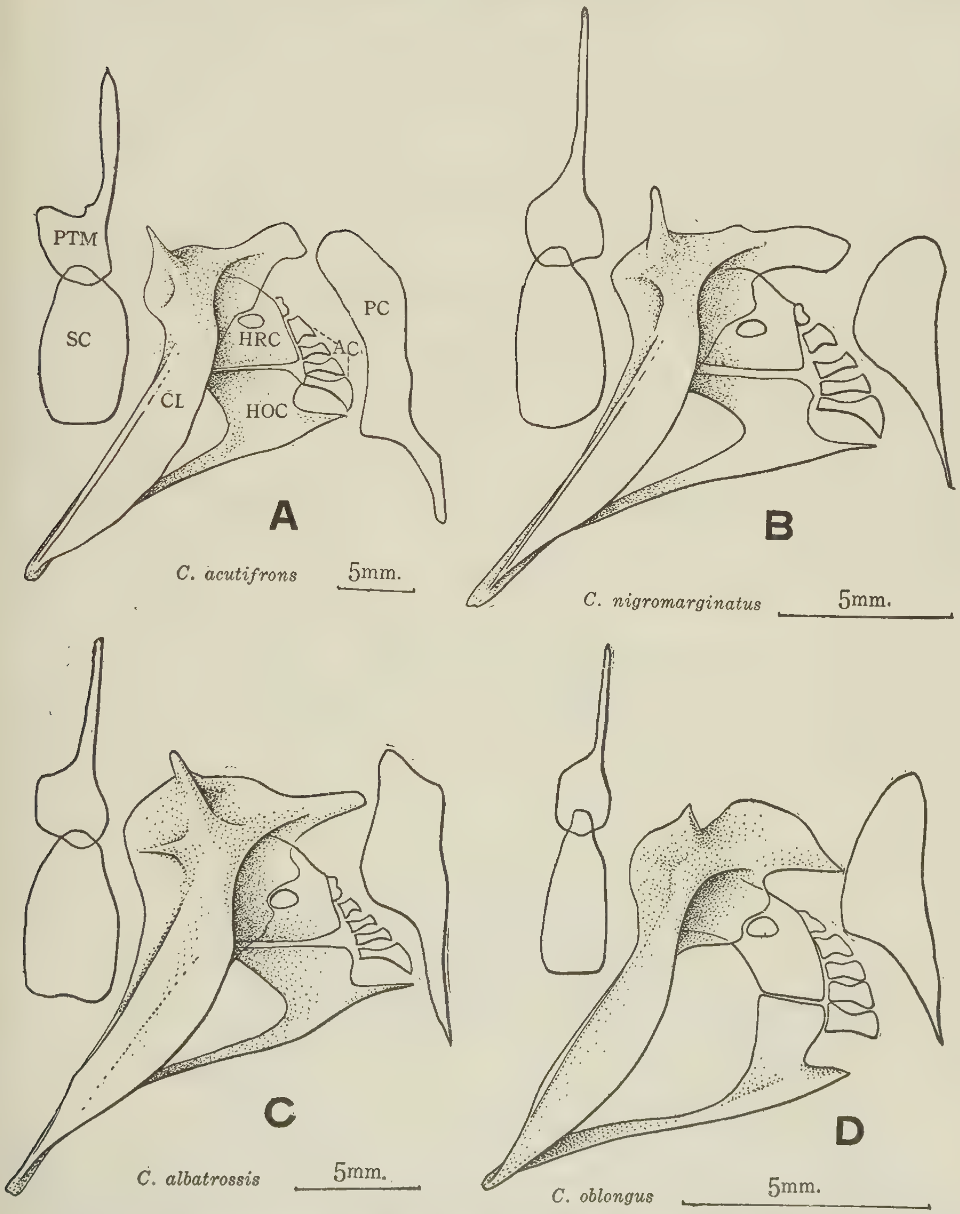
The shoulder girdle is composed with seven skeletal elements such as post-temporal, supraclavicle, clavicle, hypercoracoid, hypocoracoid, post-clavicle and actinost, and the mesocoracoid is absent. The clavicle is a large elongated bone, broad at the curved part. Posteriorly the bone is attached to both the hypercoracoid and hypocoracoid. A circular foramen is situated in the centre of the hypercoracoid. In the three species, with exception of *C. oblongus*, the

interosseous space is formed by the posterior margin of clavicle and the hypocoracoid, whilst in *C. oblongus* the space is enclosed by the clavicle, hypercoracoid and hypocoracoid.

Thus, *C. oblongus* is remarkably different from the others in having the above-mentioned characters. (Text-fig. 5)

7. Hyoid arch

The hyoid arch is composed with seven skeletal elements such as interhyal,

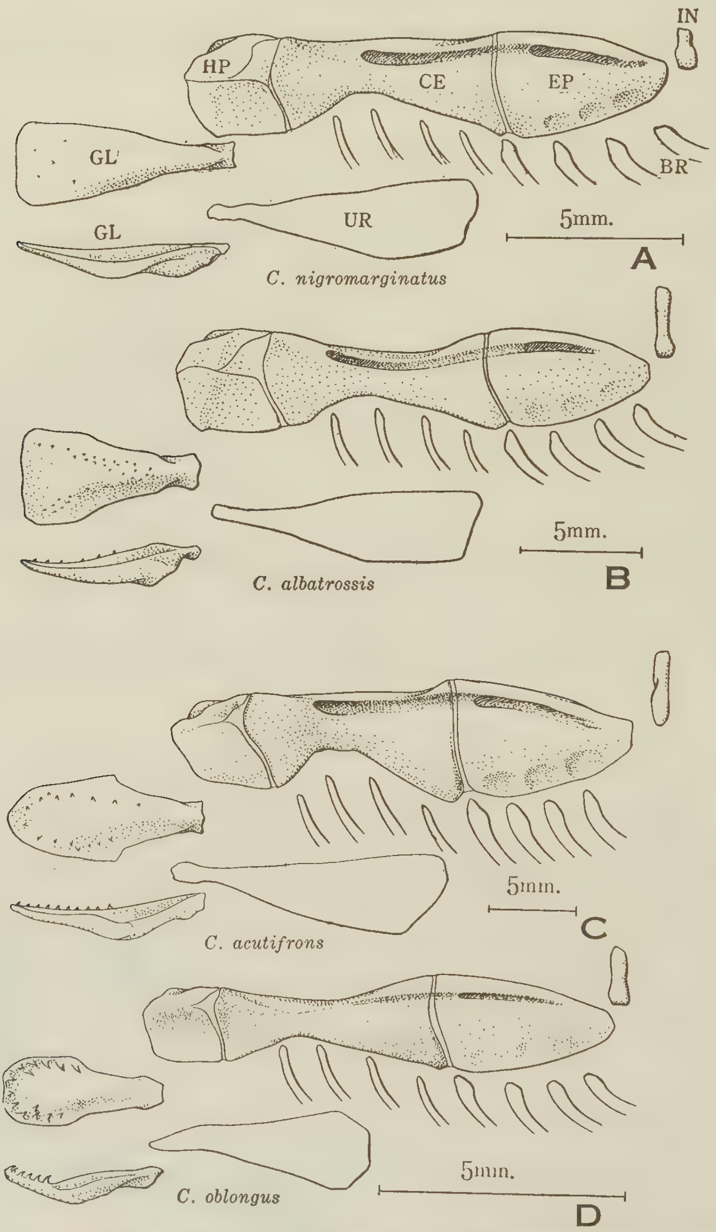


Text-fig. 5. Lateral aspects of the shoulder girdle in four species of the *Chlorophthalmus*. PTM, posttemporal; SC, supraclavicle; CL, clavicle; HRC, hypercoracoid; HOC, hypocoracoid; PC, postclavicle; AC, actinost.

epihyal, ceratohyal, hypohyals, urohyal, glossohyal and branchiostegals.

The conspicuous difference in the hyoid arch may be expected in the shape and dentition of glossohyal.

The glossohyal is rather roundish and racket-like in dorsal aspect in *C.*



Text-fig. 6. Lateral aspects of the hyoid arch in four species of the *Chlorophthalmus*. GL, glossohyal; HP, hypohyal; CE, ceratohyal; EP, epihyal; IN, interhyal; UR, urohyal; BR, branchiostegal rays.

oblongus, but it is angulated in the others. In *C. oblongus*, the conical teeth are rather numerously placed on the dorsal surface of the bone. In *C. albatrossis* and *C. acutifrons*, the teeth are not so sharp and large as in *C. oblongus*. Lastly in *C. nigromarginatus*, the teeth are few in number, and much reduce in size. (Text-fig. 6.)

8. Cranium

Dorsal view of cranium: The mesethmoid is in front, attaching to the frontals posteriorly. The frontal occupies the greater part of the dorsal surface of the cranium. The parietal extends from the posterior edge of frontal to the epiotics. The supraoccipital is enclosed by the parietals and epiotics. The prefrontals are hanging down from the anterior under portion of frontals to the anterior downward. The sphenotic situates on the upper-posterior part of orbital cavity. The pterotic forms the lateral wall of brain cavity and occupies a portion behind the sphenotic. Ventral view of cranium: The vomer is usually toothed. The parasphenoid occupies a position behind the vomer, forming a floor of the cranium. The alisphenoid situates on the under surface of frontal. The prootic situates in the postorbital part of the cranium, forming wall of the brain case with the opisthotic, exoccipital and pterotic. The exoccipital attaches posteriorly the upper portion of prootic, and is pierced through by a nervous foramen at the central part of the bone. The opisthotic is surrounded by the exoccipital, epiotic and pterotic. The basioccipital occupies the ventro-posterior part of the cranium, articulating with the first vertebra. The orbitosphenoid is not present. (Text-fig. 7)

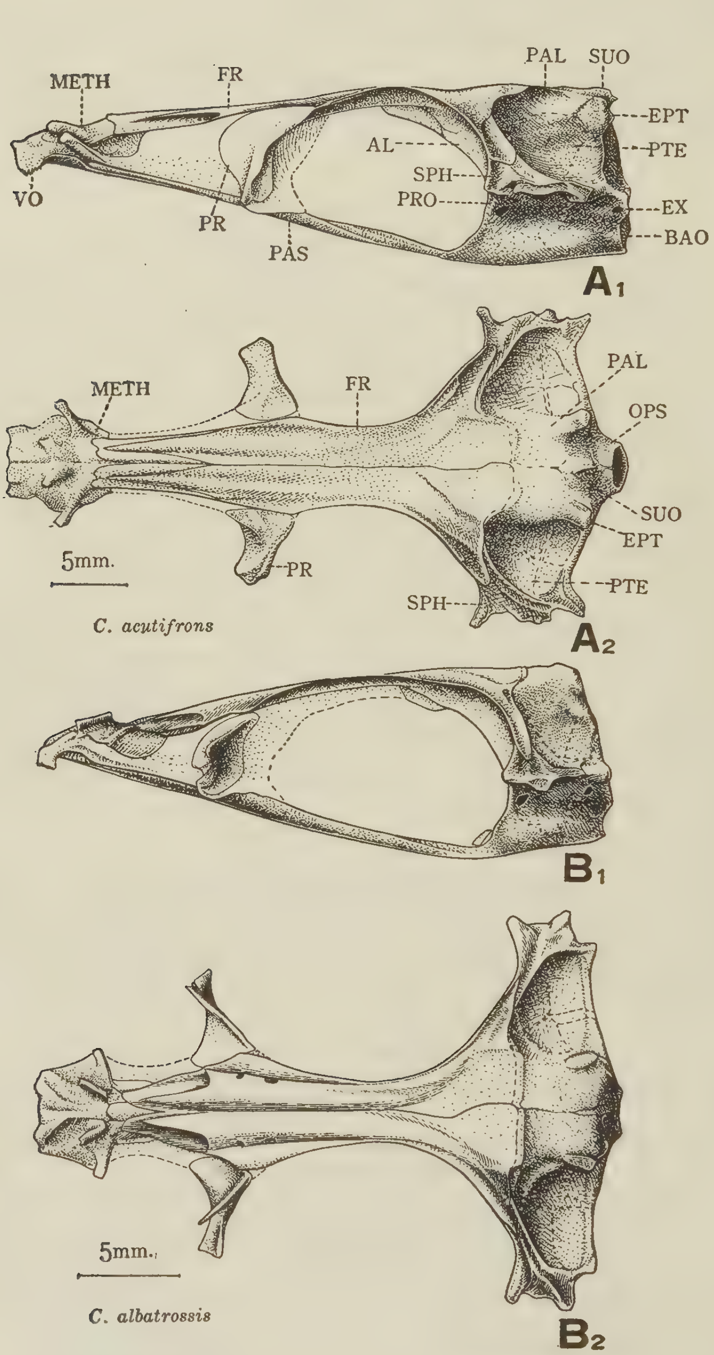
There is no substantial difference in the structure of the cranium in the four species. But, in comparison with the antorbital and the orbital portion, there is the similar result as in the relation between the snout length and the diameter of eye.

9. Number of vertebrae

The counts of vertebrae in the four species are indicated in Table 4.

Table 4. Showing the range and average of vertebrae in four species of *Chlorophthalmus*.

Items / Species	No. of individual	Range	Average
Chlorophthalmus acutifrons	10	46–47	46.1
Chlorophthalmus albatrossis	22	48–50	48.9
Chlorophthalmus nigromarginatus	5	45–47	46.0
Chlorophthalmus oblongus	2	40	40.0



Text-fig. 7. Dorsal and lateral aspects of the cranium in two species of the *Chlorophthalmus*. VO, vomer; METH, mesethmoid; FR, frontal; SPH, sphenotic; PF, prefrontal; PTE, pterotic; PR, parietal; SUO, supraoccipital; PAS, parasphenoid; BAS, basisphenoid; AL, alisphenoid; PRO, prootic; BAO, basioccipital; EX, exoccipital; OP, opisthotic; EPT, epiotic.

(The urostyle is included in the number of vertebrae.)

According to the table in *C. oblongus* the count is 40 and apparently fewer than the others.

III Conclusion

C. oblongus is remarkably different from the other three species in external and internal features.

The conspicuous differences are expected in the proportional features of body, the absence of supramaxillary, out-line of gill raker, number and out-line of lateral line scales, character of interosseous space of girdle and number of vertebrae.

The absence of supramaxillary of the present species is quite different configurations from the other species.

T. Kamohara (1953) described this species under the family *Chlorophthalmidae*. According to our observations of skeletal features of the species, the absence of supramaxillary is a most distinguishable character from the others.

We have some doubt whether the present species is included under the family *Chlorophthalmidae*, if the absence of supramaxillary will take particulary into consideration.

In the other three species, *C. albatrossis* is clearly distinguished in having shorter head and larger eye.

C. acutifrons and *C. nigromarginatus* are rather closely allied in the external features, but is clearly distinguished in the structure of glossohyal. In *C. acutifrons*, the glossohyal is round on the anterior margin and many well-developed conical teeth, while in *C. nigromarginatus* it is armed with few degenerated teeth and angular anterior margin.

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Further Study of Polysiphonia from Japan (II)

(*With Plates XXIV–XXXV, and Text-figures 1–17*)

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Last year the present writer reported on 10 species of *Polysiphonia* in the first part of this paper and now he deals with the remaining 20 species under the subject Part II which has been written as a result of his examination of types or authentic specimens at various European herbaria in 1958 in same manner as the Part I of this paper.

His sincere thanks are due to Miss DICKINSON in Herbarium of Royal Botanic Gardens, Kew, Mrs. BUTLER, British Museum, London, Prof. FELDMANN in Oceanographic Institute, University of Paris, Dr. HENDERSON, Dr. GREEN and Miss PRENTICE in Botanical Laboratory, Royal Botanic Garden, Edinburgh, Dr. KOSTER in Rijksherbarium, Leiden, Holland, Mrs. KYLIN and Dr. PETERSON in Botanical Museum, University of Lund, Sweden and Prof. WEBB and Mr. ROBERT in School of Botany, Trinity College, Dublin, for their kind assistance and permissions to examine their precious herbaria. His heartily thanks are also due to the directors and photographers of Royal Botanic Gardens, Kew, and Rijksherbarium, Leiden, who kindly sent him the photographs of two specimens (Pl. XXVIII, D and Pl. XXXII).

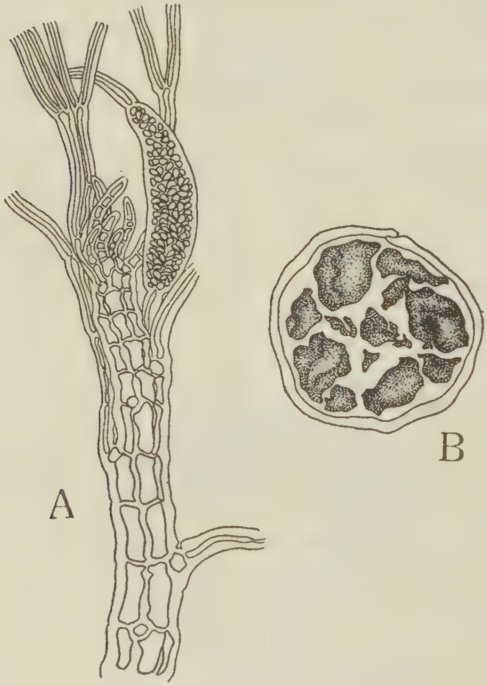


Fig. 1. *Polysiphonia fibrata* (DILLWYN) HARVEY. A. Upper part of the branch bearing antheridium. ×50; B. Transverse section of the basal part of the frond. ×100. (Authentic specimen from Malahide, Eire)

Polysiphonia yendoi SEGI

(Pl. XXIV and Text-fig. 1)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 211–214, Pl. VI, 1, 2, Text-fig. 15.

When the present writer described this species in 1951, he already compared it with British

and Irish specimens of *P. fibrata* (DILLWYN) HARVEY preserved in Japan. At that time he cleared the anatomical structure of the fronds, especially the presence of trichoblast-connecting branches on them. This time he was able to examine the isotype and authentic specimens of *P. fibrata* HARVEY from Falmouth, England and Malahide, Eire in the herbarium of Harvey, Trinity College, respectively. In the outer appearance also they coincide with those specimens which were examined in Japan formerly. In the Irish plant from Malahide the filaments are 360 μ thick and the articulations are ca. 1.3 times as long as diam. at the lower part of the branch, 165 μ thick and ca. 2 times at the middle part of the branch, 75 μ thick and ca. 2.2 times at the upper part of the branch. The fronds of these specimens are composed of 4 siphons with cortical cells at the lower part. Fortunately the writer could observe some male reproductive organs.

Polysiphonia spinosa (AGARDH) J. AGARDH

(Pls. XXV, XXVI, A–C and Text-fig. 2)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 214–216, Pl. VI, 3.

The present writer was able to have an opportunity to examine the authentic specimens of this species (No. 39008–39022, Venice) in the Agardhian herbarium, Lund. The frond of No. 39018 (dark in colour, rather membranaceous) coincides with that of the Japanese specimen in general, but there is such a small discrepancy between these two specimens that the frond is nude at the upper part in the Japanese one, while he observed spinous branchlets even at the upper part of the frond in the European one (No. 39018). The frond of No. 39013 is rather branched in a fibrillose manner and clustered near the upper part of its branchlets. It assumes a brown colour. The lower part of the frond is coarse, rigid and darker than the upper. The frond of No. 39016 is coarse and robust, issuing spinous branchlets on the whole part of it (Fig. 2), which rise irregularly in opposite directions or a verticillate manner. It is composed of 4 siphons with cortical cells and presents a dark blackish brown colour, adhering to paper only at the upper part of the frond.

Fig. 2. *Polysiphonia spinosa* (AGARDH) J. AGARDH. Frond. ×2. (Authentic specimen from Venice No. 39016)

Besides these specimens, the writer could examine the authentic specimen collected by ZANARDINI in the herbarium of HARVEY, Trinity College, Dublin. It coincides with No. 39018 in general and assumes a light greenish brown colour.

Formerly the present writer discussed a difficulty of distinction between *P. spinosa* and *P. flexella*. As a result of his study in Agardhian herbarium, Lund, he has observed that sometimes it is rather difficult to distinguish the one from the other, but they often can be distinguished from each other by the following characteristics. In *P. flexella*, generally the frond is branched in a villous manner, issuing tufted branchlets and the spineformed branchlets are more obscure than those of *P. spinosa*.

The present writer could examine the authentic specimens (No. 40713–40717, Coll. Cabrera, Gades) of *P. flexella* in Agardhian herbarium, Lund. In the frond of them, spineformed branchlets are villous and densely tufted. They are dark brown in colour. The frond of No. 40705 specimen (Tingin, Schousboe) is small, ca. 3.5 cm. high and several times branched in a dichotomous manner. Spineformed branchlets shoot out all over the frond, congesting only at its upper part. In the lower part of the frond this specimen approaches *P. spinosa* in some degree. The frond of No. 40702 specimen (Marseille, Oct. 1871) attains to ca. 12 cm. in height and also is villous. The main axis (filament) is coarse in substance. The branchlets are densely tufted, issuing fine, hairlike ultimate branchlets. The frond is somewhat attached to paper except at the basal part, while the ultimate branchlets are attached to paper firmly. It is reddish brown in colour.

Polysiphonia harlandii Harvey

(Pl. XXVI, D and Text-fig. 3)

Segi, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 216–218, Pl. VII, 1, Text-fig. 16.

This time the present writer was able to examine the authentic specimen (isotype, Herbarium of the U.S. North Pacific Exploring Expedition under Commanders Ringgold and Rodgers, 1853–56, C. Wright Coll., Hong Kong) in the herbarium of Harvey, Trinity College, Dublin. It is preserved in the genus cover noted with "122 *Pol. Harlandii* H. China". The Formosan specimen coincides well with this authentic one both in outward appearance and inner structure of the frond. The main filament of Hong Kong specimen is very thick in the lower part, reaching ca. 825 μ. It measures ca. 255 μ thick at the middle, ca. 180 μ thick at the upper part of the frond. The frond is composed of 4 siphons with many cortical cells. It is tetrasporic frond.

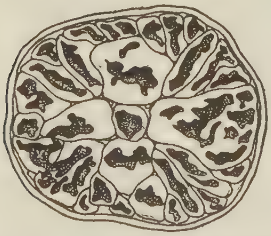


Fig. 3. *Polysiphonia harlandii* Harvey. Transverse section of the basal part of the frond. ×60. (Isotype specimen from Hong Kong).

Polysiphonia decumbens SEGI

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 218–221, Pl. VII, 2, Text-figs. 17–18.

When the writer described this species previously, he noted its resemblance to *P. savatieri* HARIOT. This time he could examine the latter in the general herbarium at Museum of Cryptogamy, Paris (cf. Part I of this paper p. 263). In the former the frond is composed of 4 siphons with cortical cells, while in the latter the frond consists of 4 siphons with no cortical cells. On this point they are distinguishable each other.

Polysiphonia nipponica SEGI

(Pl. XXVII, A–C and Text-fig. 4)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 221–225, Pl. VII, 3, Text-figs. 19–20.

When the present writer described this species formerly, he compared it with *P. fibrillosa* GREVILLE based on the description. This time he could examine in person the authentic specimen (Isotype, Herb. A. LE JOLIS, GREVILLE COLLECTION, Cherbourg, France, July, 1856) in the GREVILLE COLLECTION, Royal Botanic Garden, Edinburgh. According to this examination as well, the Kaike specimen shows a strong resemblance to the Cherbourg one in outward appearance. The frond of the Cherbourg specimen is densely branched in a fasciculate manner at the upper part. It is more tufted than that of the Komi specimen, being blackish brown in colour and adhering to paper in drying.

In another specimen of *P. fibrillosa* GREVILLE (Hofmansgave, Denmark, HORNEMANN) the frond is fine and female. The present writer could figure the cystocarp clearly (Fig. 4).

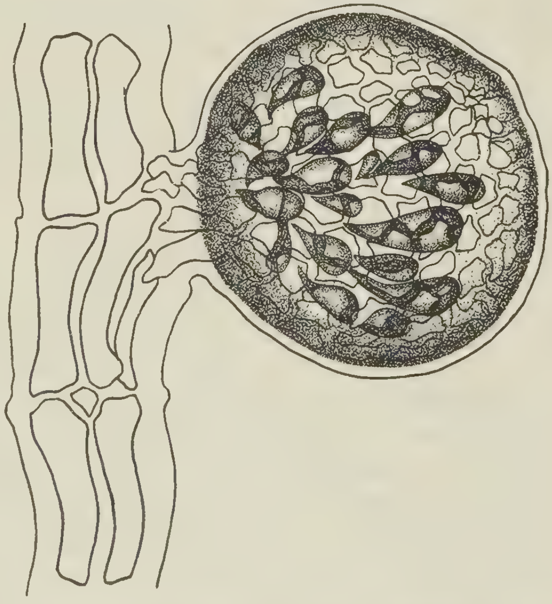


Fig. 4. *Polysiphonia fibrillosa* GREVILLE. Cystocarp. ×120. (Isotype specimen from Cherbourg)

As noted above, the two species resemble much each other in outward appearance, but they are distinguishable by the type of origin in branches (cf. cited above paper, 1951, p. 225).

In addition, the present writer discussed the difference between *P. fibrillosa* GREVILLE and *P. violacea* (ROTH) GREVILLE in the previous paper. This time he could examine the authentic specimen (Isotype, Halifax, HARVEY) of the latter as well in GREVILLE COLLECTION, Edinburgh. According to this new examination, the two species are different from each other as noted by KYLIN. (cf. 1. c.).

Polysiphonia novae-angliae TAYLOR
(Pl. XXVII, D and Text-fig. 5)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 226-228, Pl. VIII, 2, Text-fig. 21.

Fig. 5. *Polysiphonia novae-angliae* TAYLOR. Transverse section of the basal part of the frond. ×60. (authentic specimen from New Bedford, Mass. U.S.A.)

Unexpectedly the writer could examine the authentic specimen (Herb. WILLIAM RANDOLPH TAYLOR, Black rock, New Bedford Hbr. Mass., Coll. TAYLOR, 7-28-31) of this species in Rijksherbarium, Leiden. In the American specimen, branches are densely tufted, forming a mass, while in the Japanese one they are not so congested as those of the former. In general, however, they coincide each other. The frond of American specimen is composed of 4 siphons with cortical cells.

Polysiphonia japonica HARVEY
(Pl. XXVIII, A-C and Text-fig. 6)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 228-232, Pl. VIII, 3, Text-fig. 22.

The writer could examine the authentic (isotype) specimen of *P. japonica* in the herbarium of HARVEY, Trinity College, Dublin.

At the top of a board inserted in the genus cover noting "207 *Pol. japonica* H. Japan", there is a specimen from Hakodate. The frond is thick and bushy. The branches are aggregated as a tuft. At the lower part of the specimen there is a label noted as "I Spec. Hakodadi, May 1854". This specimen coincides with that of Oshoro (Coll. 1945, 9, 11) growing on *Grateloupia*. At the left part of the board there is a small envelope noted as "with cystocarps, *Polysiphonia japonica* HARVEY, Wei hai-Wei, leg. Dr. P. H. BOYDAN, Comnō Mrs. E. S. GEPP. Feb. 1904". The frond is small and cystocarpic. The cystocarp is globose or broadly urceolate in shape and figured clearly by the writer (cf. Fig. 6). This coincides with the small Japanese frond from Omaezaki, growing on *Halymenia*.

The specimen at the lowermost part of the board is growing on *Sargassum*. It's label is noted as "Herbarium of the U.S. North Pacific Exploring Expedition

under Commanders RINGGOLD and RODGERS, 1853–56, C. WRIGHT Coll. Japan." The frond is thick, ca. 270–330 μ diam. at the lower part. It is composed of 4 siphons with cortical layer.

As noted above, the specimen from Oshoro growing on *Grateloupia* and

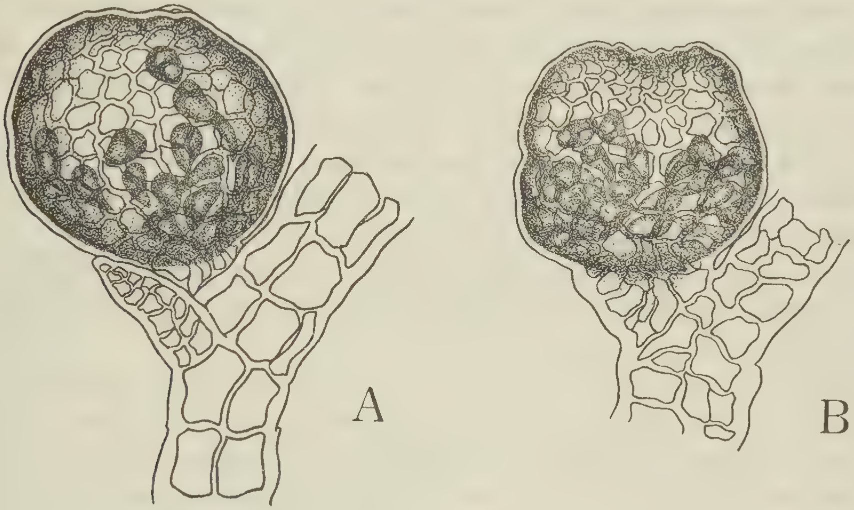


Fig. 6. *Polysiphonia japonica* HARVEY. A–B, Cystocarps. ×120. (Isotype specimen from Japan)

that from Omaezaki growing on *Halymenia* coincide with the specimens preserved in Trinity College. The fronds of Ikawatsu and Shimmaiko specimens are finer than those in this College, but they may as well be identified with this species.

Polysiphonia akkeshiensis SEGI

SEGI, The genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 232–236, Pl. IX, 1–3, Text-figs. 23–24.

The specimens from Kojima show a resemblance to those of *P. japonica*, besides *P. violacea*. Being compared with authentic specimens (isotype, Hakodadi, May 1854; with cystocarps, Wei hai-Wei, leg. Dr. P. H. BOYDAN, Comnō Mrs. E. S. GEPP, Feb. 1904) of *P. japonica* in Trinity College, the cystocarp of *P. akkeshiensis* is narrow globose or ovate in shape, while that of *P. japonica* is broadly globose or urceolate as noted in the preceding chapter.

On the other hand the specimen from Akkeshi resembles that of *P. elongella* HARVEY (Herb. LE JOLIS, Cherbourg, 15 mari 1856). The frond in Akkeshi specimen is not so tufted and elongated as that of *P. elongella*. But regretfully the writer could not observe any inner character of it.

Polysiphonia abscissa HOOKER et HARVEY
(Pl. XXVIII, D, E)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 236–238, Pl. IX, 4, Text-fig. 25.

The writer was able to examine the type specimen (St. Martin's Cove, Cape Horn, In deep water) of *P. abscissa* in the herbarium of HOOKER, Kew Gardens, London. The frond of this specimen is spreading, attaining to 9 cm. in height. It has a central axis which is of the same thickness as its branches and it is dichotomously branched in an alternate or a secund manner, spreading to show a pyramidical outline. It is not congested into a tuft, adhering to paper firmly. It is of fine filament and rose in colour.

The frond in the Japanese specimen is tufted as a whole, attaining to only 3.5–4.7 cm. in height. In general, however, they are agreeable with each other.

Besides the above type specimen, the present writer could examine other two authentic specimens (Banks' peninsula, New Zealand). The frond in one of them is rather simple, tufted, attaining to 2.7 cm. in height, while that in the other one is large, tufted and branched in a pinnate manner, attaining to 6 cm. in height. The former coincides well with the Japanese one in general. The latter has a reproductive organ, resembling *P. sertularioides* in outward appearance.

In the previous paper the present writer noted that this species resembles *P. pacifica* var. *disticha* and *P. pacifica* Hollenberg. Unexpectedly the present writer could examine these American authentic specimens in Rijksherbarium, Leiden. The frond in the former (det. HOLLENBERG, San Francisco, GARDNER No. 4405, 14 Feb. 1919) is small, tufted, attaining to 1.2 cm. in height. The one in the latter (det. HOLLENBERG, Monterey County, GARDNER, 3326, May, 1916) is elongated, attaining to 13.5 cm. (but some one is 3.5 cm.). On this frond the cystocarp can be observed clearly. The cystocarp is urceolate in shape, having a narrow neck. It closely resembles that of *P. urceolata*. In general, it seems that *P. pacifica* have a stronger resemblance to *P. urceolata* than to *P. abscissa*.

Polysiphonia urceolata (DILLWYN) GREVILLE
(Pl. XXIX and Text-fig. 7)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 239–244, Pl. X–XI, 1, Text-figs. 26–27.

The present writer made a research on the type specimen of this species in Royal Botanical Garden, Edinburgh. He could not find any specimen noted as "Type", but he could observe many authentic specimens (Con. Coll. FOSLIE)

of this species in GREVILLE COLLECTION. The Cherbourg specimen (Herb. A. LE JOLIS, regarded as f. *typica*) accords with Japanese specimen (Sakaehama, Akashi) in general. This French specimen is fine and reddish brown in colour, adhering to paper in drying.

Furthermore, he could examine another authentic specimen signed as "*Hutchinsia urceolata*" (No. 39962, Faeroes) in Agardhian herbarium, Lund. It is placed on small glass plate preserved in a paper envelope. The frond is very fragile and fine, being blackish brown or almost black in colour. Fortunately he observed the cystocarps clearly on this specimen, in four shapes (elongato-urceolate, 165 × 225 μ; ovato-globose, 210 × 240 μ; pointed elongato-ovate (at the apex), 105 × 195 μ; roundish obovate (at the apex), 120 × 180 μ). The latter two kinds of cystocarps are seriated on the upper part of the frond.

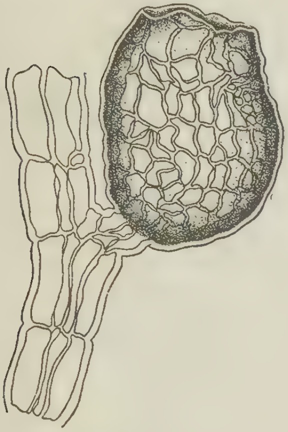


Fig. 7. *Polysiphonia urceolata* (DILLWYN) GREVILLE. Cystocarp. ×100. (Authentic specimen from Faeroes, No. 39962)

f. *patens* (DILLWYN) HARVEY

The present writer could examine the authentic specimen of f. *patens* (GREVILLE COLLECTION, Firth of Forth, Scotland, Tetrasporic frond) in Royal Botanical Garden, Edinburgh. The frond is ca. 12 cm. in height and accords well with Shikotan specimen in general.

He could examine other authentic specimen of f. *patens* (Bute, Scotland: Devonshire, England leg. GRIFFITHS) in GREVILLE COLLECTION. The fronds are small, 3–7 cm. in height and tetrasporic. Several tetrasporangia are seen in series on the upper part of branchlets continuously and rather large in size (90–120 μ diam. in Bute specimen). These specimens also accord with Japanese one in general, especially in the shape of branch, etc.

Polysiphonia morrowii HARVEY

(Pl. XXX, A–C and Tex-fig. 8)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 244–247, Pl. XI, 2, Text-fig. 28.

The present writer could examine two authentic specimens of this species in Trinity College, Dublin. The one (Herbarium of the U.S. North Pacific Exploring Expedition under Commanders RINGGOLD and RODGERS, 1853–56, C. WRIGHT Coll. Japan, Hakodadi Bay, Dredged by Mr. STIMPSON) is short, thick with stichidia growing densely and tuftedly as figured. It is blakish brown in colour. The other (Hakodadi, May, 1854) is large, attaining to 9 cm. in height, and its colour is greenish brown. The Okujiri (Yunohama) specimen accords with them

in general.

Besides these two, the present writer could examine another authentic specimen (Hakodadi, Japan, 1854) which is figured in KUETZING's Tab. Phyc. XIV, 47 (1864) in Rijksherbarium, Leiden and figured by himself also. This is a part of frond, brown in colour. The pinnate branchlet is pointed at the apex and often recurved. The tetrasporangia are sometimes produced on the pinnate branchlet, but sometimes several on the thick, short stichidia arising at the axil solitary. It is large, divided in a tripartite manner, attainining to 105–120 μ in diam.

Polysiphonia senticulosa HARVEY

(Pl. XXX, D, E and Text-figs. 9–11)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 247–251, Pl. XII, Text-figs. 29–30.

The present writer could not examine the specimen signed as "Type" clearly in Trinity College, Dublin, but could observe an authentic (isotype?) specimen of this species from Orcas Isl. V.I. (coll. Apr. 1858). This coincides with the Japanese plant

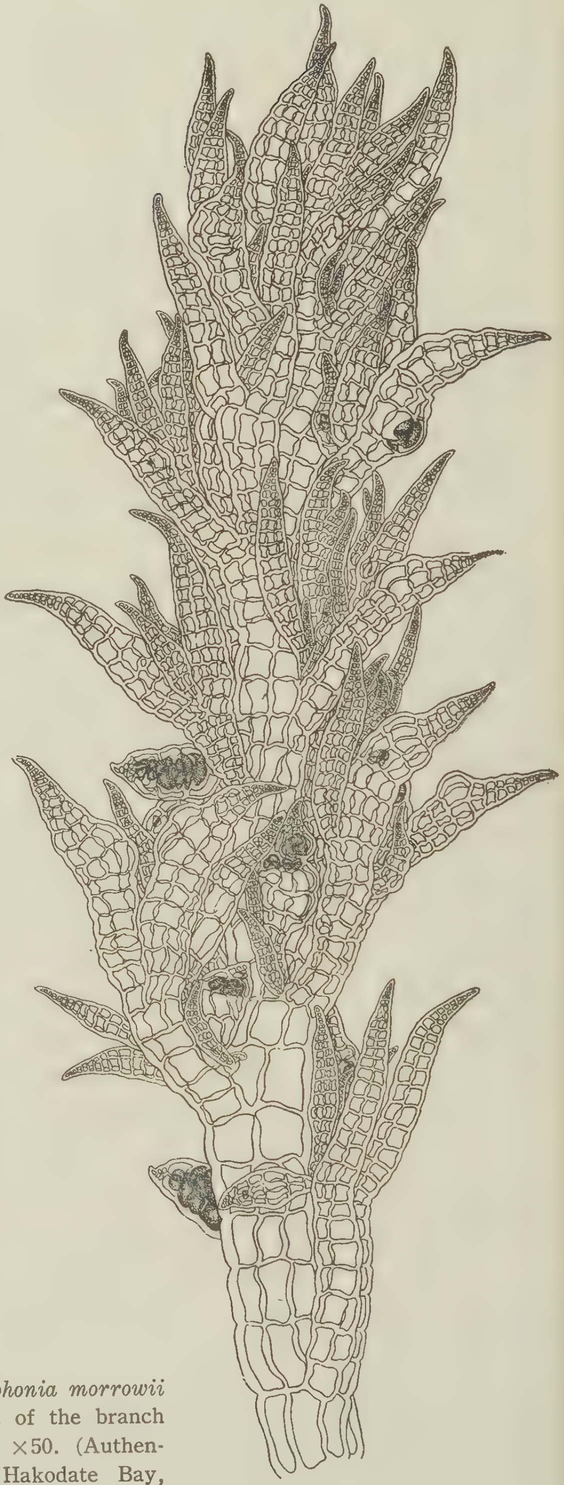


Fig. 8. *Polysiphonia morrowii* HARVEY. Upper part of the branch with tetrasporangia. ×50. (Authentic specimen from Hakodate Bay, Dredged by Mr. STIMPSON)

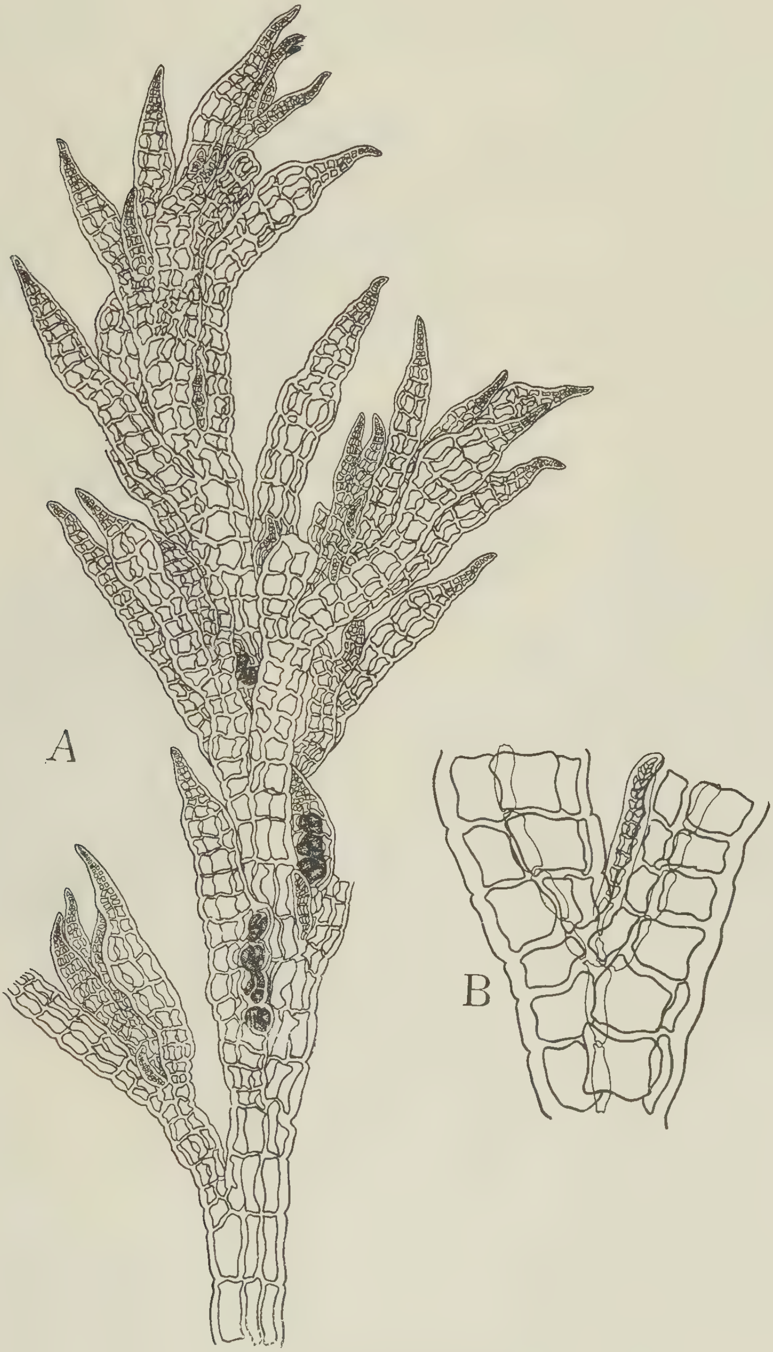


Fig. 9. *Polysiphonia senticulosa* HARVEY. A. Upper part of the branch with tetrasporangia. ×60. B. An endogenous branchlet. ×225. Authentic specimen from Orcas Isl. V. I. Type specimen of *Orcasia senticulosa* (HARVEY) KYLIN No. 40091

but it has no tendency to have its branchlet aggregated in a tufted manner. The articulation is long, ca. 195 μ in diam. and 6 times as long as diam. in the middle part of the frond.

Fortunately the present writer could examine a group of another authentic specimen belonging to *Orcasia* by KYLIN, in the Agardhian herbarium, Lund, On a board are attached four specimens (No. 40090–93).

Examining the specimen, No. 40090 (*Pol. Morrowii* HARV.=*P. senticulosa* HARV. Hakodadi, Japan, May 1854, Dr. MORROW), the branchlet is arising as tuft sometimes endogenously. On the other hand, it seems to stand near to *P. morrowii* in general. The Oma specimen resembles to this specimen in some degree. The specimen No. 40091 (*Pol. senticulosa* H., Orcas Island, V. I. April 1858) is the original specimen which is used in the description of *Orcasia senticulosa* by KYLIN. On the frond of this specimen, the present writer observed the branch resembling the endogenous branch, but he could not discern the central cell distinctly. He could observe exogenous branches also. The ultimate branchlets are often tufted. The ultimate branchlet of the Asamushi specimen is not tufted distinctly and accords with that of this specimen from Orcas Isl. On the lower part of No. 40092 (Hakodadi Bay, dredged by Mr. STIMPSON), there is a label noted as "Herbarium of the U.S. North Pacific Exploring Expedition under Commanders RINGGOLD and RODGERS, 1853–56, *Polysiphonia Morrowii* HARV. C. WRIGHT Coll. Japan". This frond is cystocarpic. The cystocarp is distinctly urceolate (262–300×450–525 μ) and could be figured by the writer clearly. In the frond of the specimen, No. 40093, (Vancouver I. Ar. C. B. Word. 1841) the stichidia is tufted in some places. The endogenous branches were also observed by the writer.

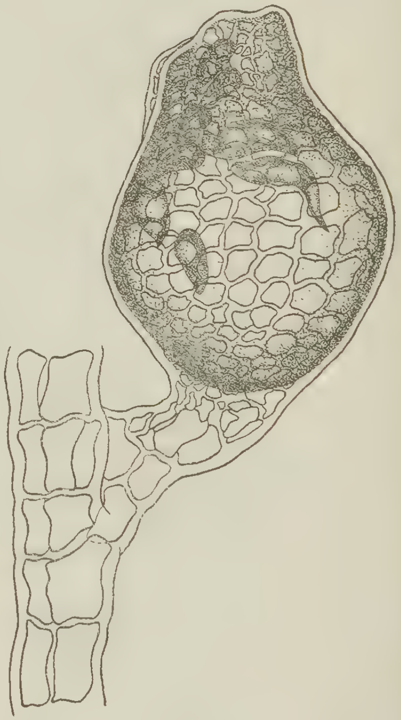


Fig. 10. *Polysiphonia senticulosa* HARVEY. Cystocarp. ×120. (Specimen from Hakodate Bay, No. 40092)

Besides the specimens noted above, the writer could examine a specimen determined as *Orcasia senticulosa* (HARV.) KYLIN (Calif. Pacific Grove, 1922) by KYLIN. Examining this, however, the frond is tetrasporic and this specimen seems to be related to *P. urceolata*, according to the mode of branching in the ultimate branches.

Noted as above, often it is rather difficult to distinguish between *P. mor-*

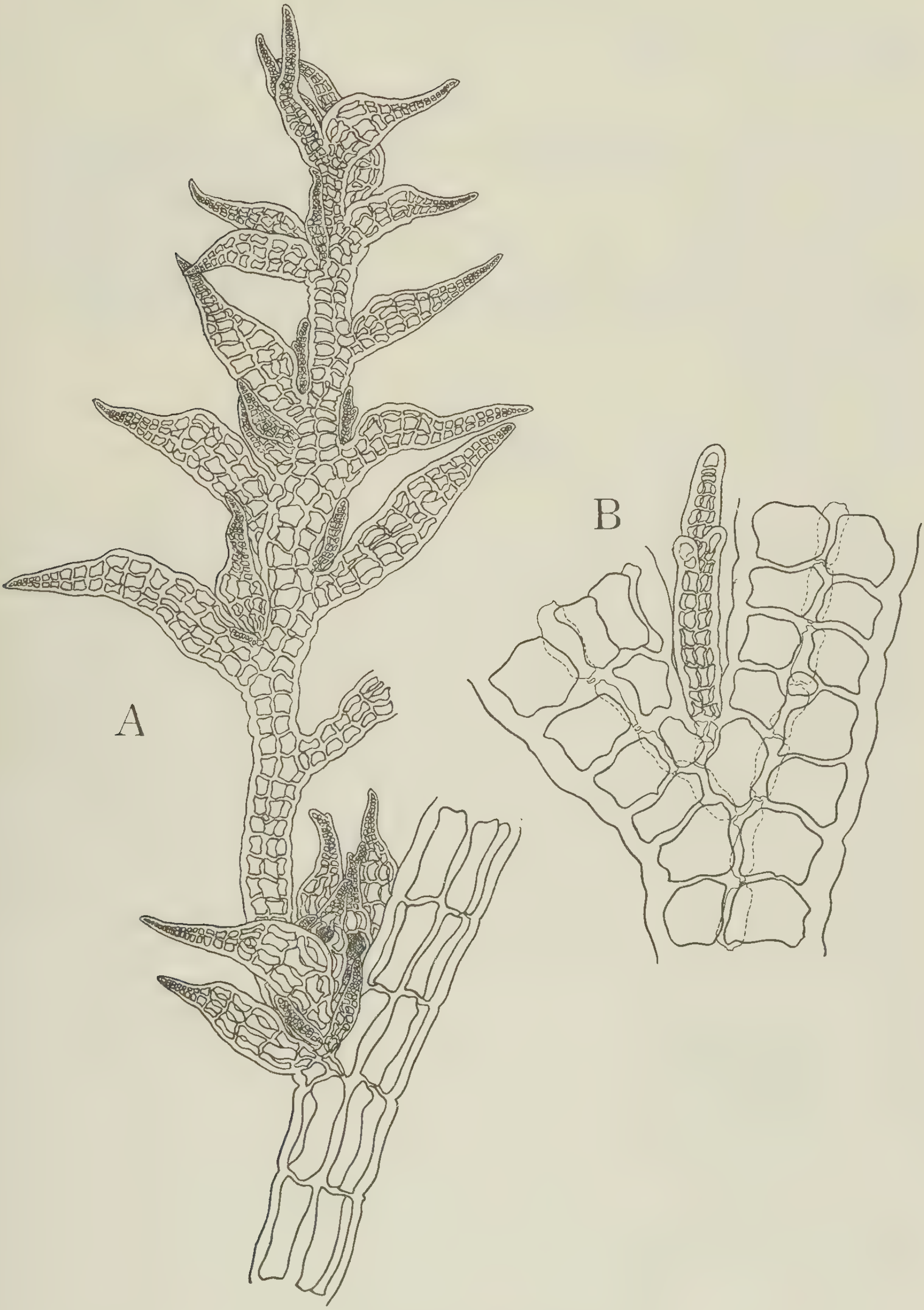


Fig. 11. *Polysiphonia senticulosa* HARVEY.

A. Upper part of the branch. ×60. B. An endogenous branchlet. ×225. (Specimen from Vancouver I., No. 40093)

rowii and *P. senticulosa*. In the latter the stichidia and pinnate branchlets are arising tuftedly, but those of the former seems to be more distinctive than those of the latter.

KYLIN reported the presence of endogenous branches in both species. According to this fact, KYLIN established the genus *Orcasia*. Sometimes in *P. Morrowii* it is indistinctive on this point while it is distinctive in *P. senticulosa*, especially in stichidia.

The writer interpreted the genus *Polysiphonia* in a broader sense and classified even this species into *Polysiphonia* as hitherto described. But it is not strange, if one may put it in *Orcasia*, interpreting the genus *Polysiphonia* in a narrower sense.

Polysiphonia fragilis SURINGAR

(Pl. XXX, F, G)

Syn. *P. forcipata* (non HARVEY) SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 251-253, Pl. XIII, 1, Text-fig. 31.

The present writer could examine the type specimens of *P. fragilis* (Herb. SURINGAR, Japan, SIEBOLD) in Rijksherbarium, Leiden. One specimen is preserved in a small envelope and the other in another small envelope, both being kept in a larger envelope noted as "TYPE!". The former (Pl. XXX, F) is a fragment, intricated and attaining to 1–1.5 cm. in height. This was used in the description of SURINGAR's Alg. Japonica. The latter (Pl. XXX, G, Herb. Lugd. Batav. 10 Eur. As. No. 903, 2····1; SIEBOLD, Japan) is small and attached on a small corkboard at each side. The frond is composed of 5 siphons, ecorticated, 225–255 μ thick in the upper part. The articulation is ca. $\frac{1}{1.5}$–$\frac{1}{2}$ as long as diam.

In the previous paper (The Genus *Polysiphonia* from Japan, 1951), he identified the specimen at hand with *P. forcipata* HARVEY. This time he could examine the type specimen of *P. forcipata* HARVEY in Trinity College, Dublin and consequently the following important characteristics are clear at present. Being different from DE TONI's description, the frond of the type specimen (ROTTNEST) is composed of 6 siphons (ecorticated) instead of 5 siphons. Moreover the apex is strongly forcipated. The frond is reddish purple in colour and rather membranaceous.

According to this reason, it seems to the writer that the specimen at hand is to be identified with *P. fragilis* instead of *P. forcipata*.

Polysiphonia richardsoni HOOKER

(Pl. XXXI and Text-fig. 12)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 253-254, Pl. XIII, 2.

The present writer could examine the type specimen of *P. richardsoni* HOOKER (Herb. RICHARDSON, Whitehill, Colvend Bay, Aug. 1823) in the herbarium of Royal Botanic Gardens, Kew. The upper part of its branch is 120–150 μ thick. The articulation is 1–2 times as long as diam. The frond is fine and is composed of 5 siphons, corticated in the lower part. It presents a reddish purple colour and does not adhere to paper in drying. The Shimmaiko specimen shows a strong resemblance to this type one in outward appearance, but in anatomical character the former seems to rather differ from the latter. So the present writer remains a doubt in some degree. Under the right side of this type specimen there is a label showing "The material on this sheet does not confirm Batten 1923, Newton 1931. There are 4 pcc. above, more below; the Segments are not longer than broad in the lower parts of the axis and the main and secondary branches are distinctly corticated, ··· (?). branchlets are naked. TAYLOR 1937."

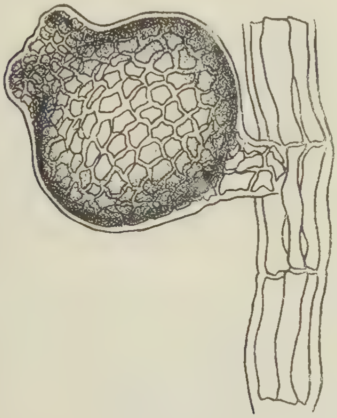


Fig. 12. *Polysiphonia richardsoni* HOOKER. Cystocarp. ×60. (Authentic specimen used in Phyc. Brit. X)

Furthermore he could observe another authentic specimen of *P. richardsoni* which is used in the description of Phyc. Brit. X in Trinity College, Dublin (Pl. VIII, B). The frond is cystocarpic and ca. 150 μ thick in the upper part. The articulation is very long (960 μ in the longest) and 6.4 times as long as diam. In the lower part of the branch it seems to be composed of 5 (?) siphons with no cortical cells so far as could be observed. The cystocarps are not arising from the axil of the branch, but scatter on the articulation of the upper filament. It is 440–495×440–600 μ in size. The frond is associated with *Ceramium* sp. and brown in colour.

Polysiphonia tapinocarpa SURINGAR

(Pl. XXXII and Text-fig. 13)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 254–256, Pl. XIII, 3, Text-fig. 32.

Fig. 13. *Polysiphnia tapinocarpa* SURINGAR. Transverse section of the basal part of the frond. ×300. (Type specimen from Japan)

The writer could examine the type specimen of *P. tapinocarpa* SURINGAR (Herb. Lugd. Bat. 10 Eur. As. 910. 184–2612) which was preserved on Japanese paper (Washi) in Rijksherbarium, Leiden. The frond is densely branched in a fibrillose manner in the lower part. At the upper part

of the frond, ultimate branchlets are arising tuftedly. The articulations are long, 75–105 μ thick, composed of 8–9 siphons. The Utsumi specimen coincides well with this type specimen in general.

Polysiphonia yonakuniensis SEGI
(Pl. XXXIII and Text-fig. 14)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 257–259, Pl. XIII, 4, Text-fig. 33.

When the present writer described this species in his previous paper, he compared it with *P. opaca* (C. AGARDH) ZANARDINI. This time he could examine the authentic specimens of *P. opaca* in European herbaria.

First he could observe the authentic specimens (No. 41631–41700, Trieste, under the name of *Hutchinsia opaca*) in Agardhian herbarium, Lund. They are fragmentary, intricated, fragile, fine fibrillose and brown in colour, growing on very small shells. They do not adhere to paper in drying.

Secondly he could examine the Venice specimen collected by ZANARDINI in Trinity College, Dublin. It is reddish brown in colour. Another he could observe the Antibes specimen collected by GIRAUDY. This is expanded to globose outline and represents also reddish brown in colour.

Fig. 14. *Polysiphonia opaca* (C. AGARDH) ZANARDINI. Transverse section of the basal part of the frond ×300. (Authentic specimen from Cyprus)

Thirdly he could examine Cyprus specimens (Flora of Cyprus, locality: Kyrenia Harbour, on sand-covered rocks, Date: March 1953, Coll: Prof. I. MANTON No. , *Polysiphonia opaca* (AG.) ZANARDINI, J. FELDMANN det. October 1953) in the herbarium of British Museum, London. The frond is composed of 14–15–16 siphons, which are more numerous than those in *P. yonakuniensis*. The relation between branch and trichoblasts is not able to be observed distinctly.

Polysiphonia porrecta SEGI
(Pl. XXXIV, A, B)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 260–263, Pl. XIV, Text-fig. 34.

When the writer described this species previously, he compared it with *P. variegata* (C. AGARDH) ZANARDINI. This time he could examine the authentic specimens of *P. variegata* (as *Hutchinsia variegata* AG., Venice, Mediterranean Sea) in Agardhian herbarium, Lund. The fronds of these specimens are about 7 cm. in height. They are densely branched in fibrillose manners and expanded in tufted manners at the upper parts.

Also he could examine another authentic specimen (Bejham? Isl.) in Trinity College, Dublin. The frond is 17 cm. in height and branched in a distinct dichotomous manner at the lower part. The upper branchlets are congested into a tuft.

Besides the above, he could examine an authentic French specimen of *P. variegata* (Herb. FELDMANN, 5772, Pempoul, Roscoff, Finistère, 29 Jul, 1946) which was presented to him by FELDMANN. The branch of this frond is broadly expanded and finely elongated, forming a tuft at the upper part. The frond is composed of 6 siphons and clearly corticated. It should be classified in "Corticate group" as noted in the previous paper.

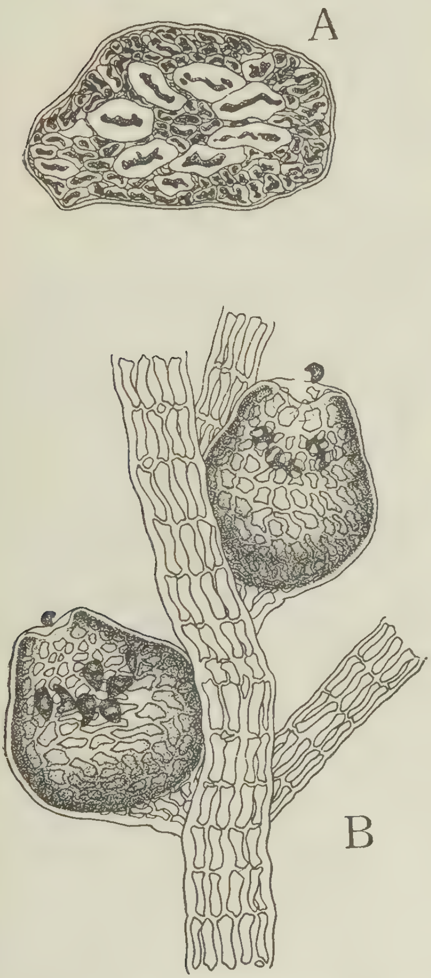


Fig. 15. *Polysiphonia brodiaei* (DILLWYN) GREVILLE. A. Transverse section of the basal part of the frond. ×60. B. Cystocarps. ×60. (Specimen from Roscoff, No. 5814)

Polysiphonia brodiaei (DILLWYN) GREVILLE

(Pl. XXXIV, C, D and Text-fig. 15)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 263-264, Pl. XV, 1.

This time the present writer could examine the isotype specimens of this species in GREVILLE COLLECTION, Royal Botanical Garden, Edinburgh. Two specimens were preserved in two envelopes separately, each being attached on one board.

The frond of one specimen (Peterhead, Scotland, V. C. 93, Coll. THOMAS BELL, June 1834) is branched in a tufted manner near the apex of the branchlets, attaining to ca. 14 cm. in height. It presents Maroon colour (Brownish-crimson) and firmly adheres to paper in drying. The Japanese plant accords with it in general.

There is another fragment specimen with a label noted as "*C. Broadiaei* named so by DILLWYN. 27". This is preserved in an envelope noted as "Lossiemouth, Scotland. (V. C. 95), leg. BRODIE, det. DILLWYN." The ultimate branchlets are aggregated into a tuft.

Besides those noted above, he examined a French specimen (Herb. FELDMANN, Roscoff, Finistère, No. 5814, Pointe de Primel, 31 juillet 1946, J. FELDMANN Leg.) which was presented by FELDMANN to him. The frond is composed of 7–8 siphons, corticated. In this frond the writer could observe variable cystocarps which are broadly or compressed urceolate in shape and ca. $390 \times 495\,\mu$ in size. The Japanese algae also accord with this specimen in general.

Polysiphonia notoensis SEGI

(Pls. XXXIV, E, XXXV and Text-figs. 16–17)

SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 266–269, Pl. XVI, 1, Text-fig. 35.

In the previous paper, the present writer noted that this species has a resemblance to *P. cancellata* in some degree. At the same time he notices a strong resemblance in this species to *P. fruticulosa* (WULFENI) SPRENGEL, so he examined many authentic specimens of *P. cancellata* and *P. fruticulosa* with the result as follows.

Fig. 16. *Polysiphonia cancellata* HARVEY. Transverse section of the basal part of the frond. ×60. (Specimen from Port Phillip, Australia)

In the herbarium of Harvey, Trinity College, he could observe many authentic specimens of *P. cancellata* (18 *Polysiphonia* Section IV, species 1 ob to III, 18 cancellatae—110 *P. cancellata*) from New Zealand, Australia. Among them there is a type specimen (1320 Van-Diemens-Land) the frond of which is divaricating and horizontally branching into several main branches as seen in Pl. XXXIV, E. It is composed of 6 siphons, ecorticated. Besides this specimen, he could examine another Australian specimen (Herb, LENORMAND, Port Phillip, Australia), of which frond is composed of 8 siphons, ecorticated.

In the herbarium of KUETZING, Rijksherbarium, Leiden, he could examine the (isotype) authentic specimen of *Polysiphonia fruticulosa* from Torquay, England which was used in KUETZING's Tab. Phyc. XIV, 28. The ultimate branchlets issuing many trichoblasts are arising numerously in a tufted manner. The frond is composed of 10–11 siphons (9 siphons, corticated in the description of KUETZING), corticated in the transverse section of the frond. Besides this specimen, he could examine two other authentic specimens of the species. The one (Herb. JOLIS, Cherbourg, 10 Août., 1837) is preserved in the genus cover noted as "14 *Polysiphonia* Section IV, species 94 to 97, 14 *Fruticulosa*, 96 *Poly-*

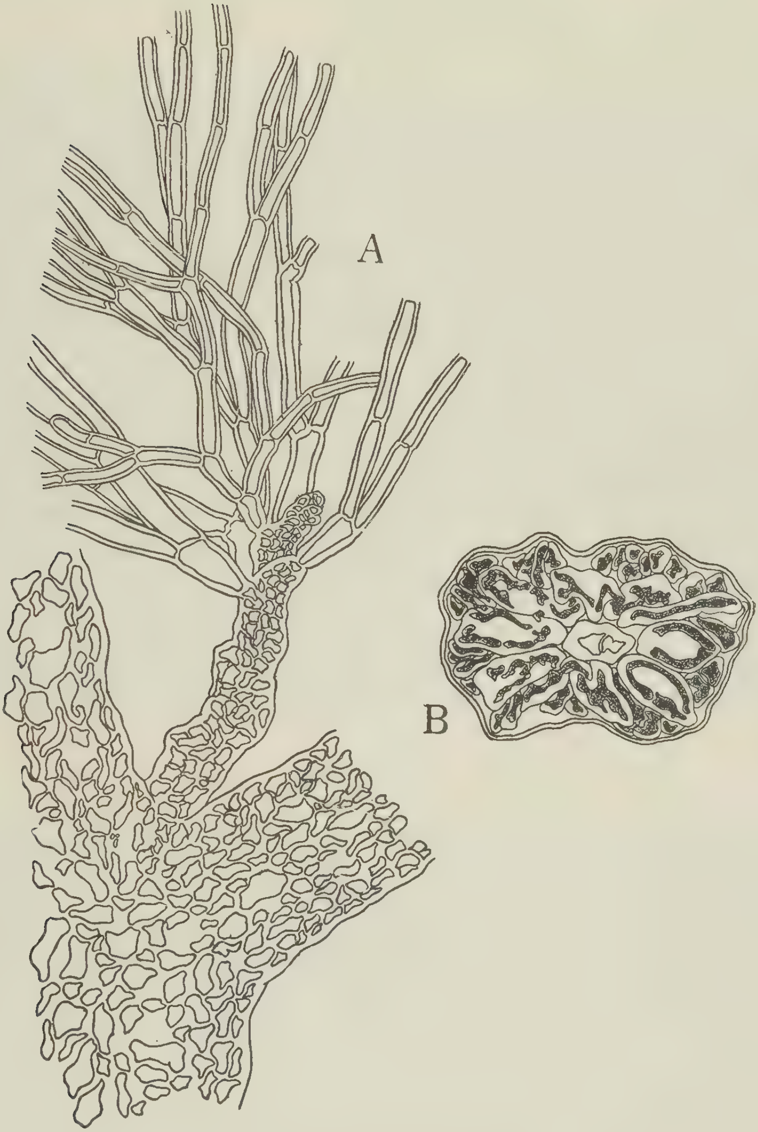


Fig. 17. *Polysiphonia fruticulosa* (WULFENI) SPRENGEL.
A. Ultimate branchlets issuing many trichoblasts. ×100.
B. Transverse section of the basal part of the frond. ×100.
(Authentic specimen from Torquay, England)

siphonia fruticulosa SPRENG." in Trinity College, Dublin. The other (Herb. FELDMANN, 5847 bis, Ile Verte, 2 août 1946, Roscoff, Finistère, FELDMANN Leg.) was presented by Dr. FELDMANN to him. The frond of these specimens are broadly expanded. The ultimate branchlets are spineformed and congested in a tufted manner. Such branchlets are scattered on the whole part of the frond in alternate manner. In the specimen from Roscoff is the frond composed of 11–12

siphons, corticated, in the transverse section.

In conclusion, the Shibagaki specimen bears a closer resemblance to *P. fruticulosa* than to *P. cancellata* both in outward appearance and anatomical character. But it can be distinguished from *P. fruticulosa* by the scantiness of characteristic, tufted branchlets seen in the latter. In addition, it is not rare that the frond of *P. notoensis* is composed of fewer siphons than that of *P. fruticulosa* in writer's observations.

Polysiphonia spec.

Syn. *P. fruticulosa* (non SPRENGEL) SEGI, The Genus *Polysiphonia* from Japan (Jour. Fac. Fish. Pref. Univ. Mie, Vol. 1, No. 2, 1951) p. 264–266, Pl. XV, 2.

The present specimen from Kobe is tentatively referred to *P. fruticulosa* in the previous paper. According to the writer's examination of both *P. cancellata* and *P. fruticulosa* in European herbaria as noted in above chapter the Japanese species appears to bear a closer resemblance to *P. cancellata* than to *P. fruticulosa* in outward appearance. In the anatomical character, however, the present species and *P. cancellata* are different from each other distinctly. So it seems to him more reasonable to refer this plant to *P.* spec. than to *P. fruticulosa* until more abundant Japanese material can be obtained.

A

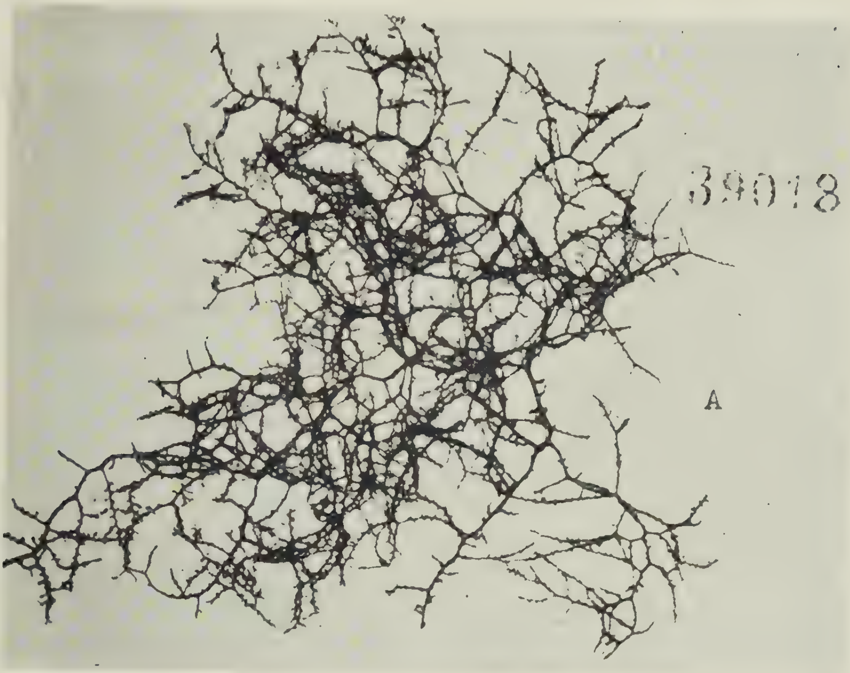
B

Explanation of Plate XXIV

Polysiphonia fibrata (DILLWYN) HARVEY

A. The isotype specimen from Falmouth, England in the herbarium of HARVEY. ×ca. 1.

B. An authentic specimen from Malahide, Eire in the herbarium of HARVEY. ×ca. 1.



A

B

Explanation of Plate XXV

Polysiphonia spinosa (AGARDH) J. AGARDH.

A. An authentic specimen from Venice in the herbarium of J. AGARDH. No. 39018. ×ca. 1.

B. An authentic specimen (ZANARDINI) in the herbarium of HARVEY, Trinity College. ×ca. 1.

B
D
A
C

Explanation of Plate XXVI

A–C, *Polysiphonia flexella* J. AGARDH

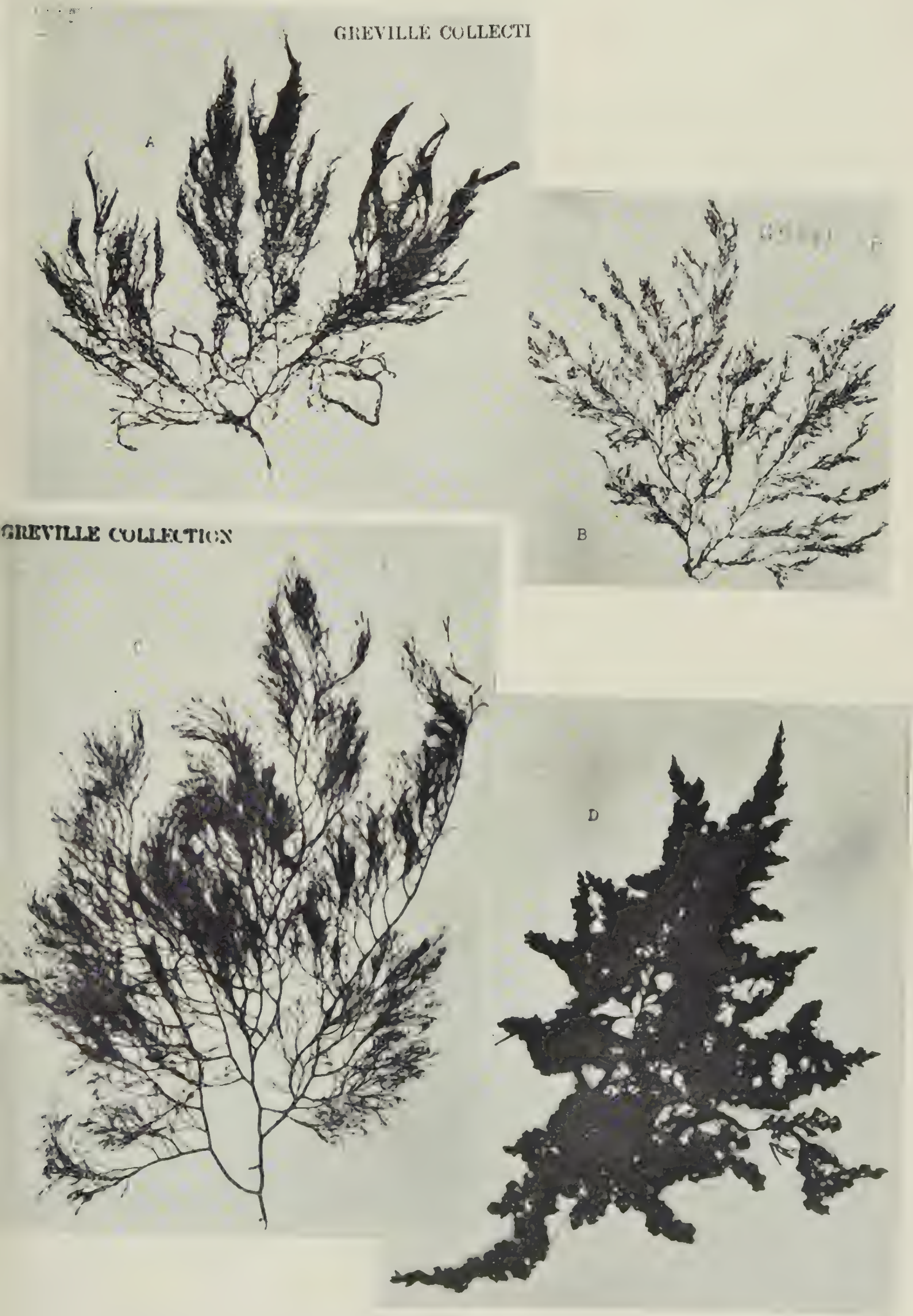
A-B. Authentic specimens from Gades under the name of *Hutchinsia flexella* AG. in the herbarium of J. AGARDH. No. 40713, No. 40716. ×ca. 1.

C. An authentic specimen from Tingin in the herbarium of J. AGARDH. No. 40705. ×ca. 1.

D, *Polysiphonia harlandii* HARVEY

D. The isotype specimen from Hong Kong in the herbarium of HARVEY. ×ca. 1.

Plate XXVII



Explanation of Plate XXVII

A–B. *Polysiphonia fibrillosa* GREVILLE

A. The isotype specimen from Cherbourg in the herbarium of GREVILLE. ×ca. $\frac{2}{3}$.

B. An authentic specimen from Hofmans Gave, Denmark. ×ca. $\frac{2}{3}$.

C. *Polysiphonia violacea* (ROTH) GREVILLE

C. The isotype specimen from Halifax, Nova Scotia. ×ca. $\frac{2}{3}$.

D. *Polysiphonia novae-angliae* TAYLOR

D. An authentic specimen from New Bedford, Mass., U.S.A. ×ca. $\frac{2}{3}$.

E
A
C
B
D

Explanation of Plate XXVIII

A–C. *Polysiphonia japonica* HARVEY

A–B. The isotype specimen from Japan in the herbarium of HARVEY. ×ca. 1.

C. An authentic specimen from Hakodate in the herbarium of HARVEY. ×ca. 1.

D–E. *Polysiphonia abscissa* HOOKER et HARVEY

D. The type specimen from Cape Horn in the herbarium of HOOKER. ×ca. 1.

E. An authentic specimen from Banks' Peninsula, New Zealand, in the herbarium of HOOKER. ×ca. 1.

C
D
E

Explanation of Plate XXIX

A–C. *Polysiphonia urceolata* (DILLWYN) GREVILLE

A, C. Authentic specimens from Cherbourg in the herbarium of GREVILLE. ×ca. $\frac{2}{3}$.

B. An authentic specimen from Faeroes under the name of *Hutchinsia urceolata* AGARDH in the herbarium of J. AGARDH No. 39962. ×ca. $\frac{2}{3}$.

D–E. *Polysiphonia urceolata* (DILLWYN) GREVILLE

f. *patens* (DILLWYN) HARVEY

D. An authentic specimen from Firth of Forth, Scotland in the herbarium of GREVILLE. ×ca. $\frac{2}{3}$.

E. An authentic specimen from Bute, Scotland in the herbarium of GREVILLE. ×ca. $\frac{2}{3}$.

A
B
C
D
E
F
G

Explanation of Plate XXX

A–C. *Polysiphonia morrowii* HARVEY

A. An authentic specimen from Hakodate Bay dredged by Mr. STIMPSON in the herbarium of HARVEY. ×ca. $\frac{2}{3}$.

B. An authentic specimen from Hakodate in the herbarium of HAREY. ×ca. $\frac{2}{3}$.

C. An authentic specimen from Hakodate in the herbariun of KUETZING. ×ca. $\frac{2}{3}$.

D–E. *Polysiphonis senticulosa* HARVEY

D. An authentic (Isotype?) specimen from Orcas Isl. V. I. in the herbarium of HARVEY. ×ca. $\frac{2}{3}$.

E. An authentic specimen from Orcas Isl. Type specimen of *Orcasia senticulosa* (HARVEY) KYLIN. No. 40091. ×ca. 1.

F–G. *Polysiphonia fragilis* SURINGAR

F. The type specimen from Japan in the herbarium of SURINGAR. ×ca. 1.

G. The type specimen from Japan attached on a small corkboard in the herbarium of SURINGAR. ×ca. 1.

Herb. Richardson
recd 10/77
A

Explanation of Plate XXXI

Polysiphonia richardsoni HOOKER

A. The type specimen from Colvend Bay in the herbarium of RICHARDSON. ×ca. $\frac{3}{4}$.

B. An authentic specimen in the herbarium of HARVEY. ×ca. $\frac{3}{4}$.

TYPE!

Explanation of Plate XXXII

Polysiphonia tapinocarpa SURINGAR

The type specimen in the herbarium of SURINGAR. × ca. $\frac{3}{5}$

A
B
C
D
E
CM 1

Explanation of Plate XXXIII

Polysiphonia opaca (C. AGARDH) ZANARDINI

A-B. Authentic specimens from Trieste in the herbarium of J. AGARDH. No. 41665, No. 41667 ×ca. 1.

C. An authentic specimen (ZANARDINI) from Venice in the herbarium of HARVEY. ×ca. 1.

D. An authentic specimen from Antibes in the herbarium of HARVEY. ×ca. 1.

E. An authentic specimen from Cyprus in the herbarium of HOOKER. ×ca. 1.

Explanation of Plate XXXIV

A–B. *Polysiphonia variegata* (C. AGARDH) ZANARDINI

A. An authentic specimen from Venice under the name of *Hutchin sia variegata* AGARDH in the herbarium of J. AGARDH. No. 41114. × ca $\frac{2}{3}$.

B. An authentic specimen in the herbarium of HARVEY. ×ca. $\frac{2}{3}$.

C–D. *Polysiphonia brodiaei* (DILLWYN) GREVILLE

C. The isotype specimen from Peterhead, Scotland in GREVILLE COLLECTION. ×ca. $\frac{2}{3}$.

D. An authentic specimen from Lossiemouth, Scotland in GREVILLE COLLECTION. ×ca. $\frac{2}{3}$.

E. *Polysiphonia cancellata* HARVEY

E. The type specimen from Van-Diemens-Land in the herbarium of HARVEY. ×ca. $\frac{2}{3}$.

A
P. fruticulosa

B

Explanation of Plate XXXV

Polysiphonia fruticulosa (WULFENI) SPRENGEL

A. An authentic (Isotype) specimen from Torquay, England in the herbarium of KUETZING. ×ca. 1.

B. An authentic specimen from Cherbourg in the herbarium of HARVEY. ×ca. 1.

Report of Faculty of Fisheries.
Prefectural University of Mie,
Vol. 3, No. 3, December 15, 1960.

Purification of Edible Oyster

TADAO SATOH

(*With Text-figures 1-6, Tables 1-2*)

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Introduction

In view of the fact that oyster are eaten raw or slightly cooked, there should be a great care concerning its sanitary condition. It is a common knowledge that oysters are raised in bay or shallow water near the sea coast which is easily affected by inland waters. Streams and rivers are directly contaminated by the influx of sewage and drainage from the places of habitation. This situation is especially true in this country where sewage sanitation is poor. Moreover, night-soil is used in the fields so that water system leading down to the river must be thought of being highly polluted.

Text-fig. 1. Oyster Cultivation Ground at Matoya, Mie Prefecture

Contagious diseases such as typhus, dysentery and many others affecting the digestive system has been reported raged through the medium of oyster food. Accordingly, in America, England, France and Holland, control over the growing of oyster is strictly enforced so that oysters reaching the market must be free from disease causing organisms.

Oysters are provided by nature with the ability of excrete in a short time the filth within their bodies by ciliary movement of the gills and excretory action of the digestive organs. This is the so-called self-purification of the oysters which can be accomplished in clean sea water. Utilizing this power of the oyster to improve its hygienic condition an experiment was performed at an ideal site in Matoya bay. This did not prove a success, there was also

contamination of the water during unfavorable weather condition. From commercial point of view, this is also a failure since offshore water where there is less danger of pollution, there is a fear for sneak-thief visiting instead. Besides there is also difficulty of operation during unfavorable sea condition.

Summarizing all the above facts, we could feel the great need for the purification of oysters as well as other edible shellfishes and there is no better way other than artificial purification.

Text-fig. 2. The Purification Plant, compartments.

Author experimented artificial purification of edible oyster, and originated new effective method of artificial purification of edible oyster by running water system in 1953.

According to the experimental results, a purification plant was established for the practical purpose at Matoya Village in Mie Prefecture in February, 1954.

In this paper, author describe about out line of the apparatus and method of purification.

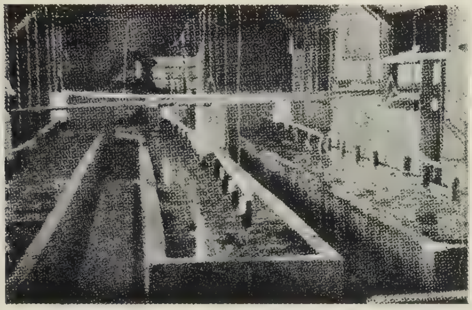
Materials and Methods

Set Up: The purification plant is housed in one storey building covering an area of 141.5 sq. meters. (As shown in Text-fig. 4, it is divided into different compartments: (1) Shell washing, (2) Purifying, (3) Sea water sterilizing, (4) Packing room). 2 horse power engine is employed to pump sea water 40 meters offshore through a lead-plated poly vinyl chloride pipe having 2 inches diameter, to the (5) tank with a capacity of 12 tons located just behind the house. From here water flows to the different compartments by means of gravity.

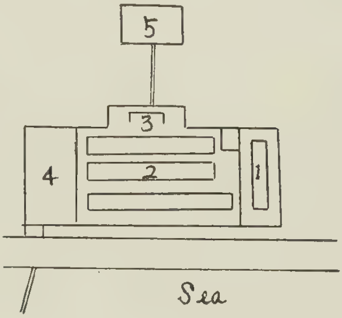
First, sea water is conveyed to the sterilizing room where in a tiled tank of three division is installed. In the first division, water is filtered from large planktons and other floating matters by means of a plankton net (GG No. 60-mesh 58, bolting silk) fitted at the intake thus preventing clogging of sprinkler as well as making the germicidal lamp more effective at the later process. Next is the sterilizing division which has a depth of 23 cm. and having a capacity of 90 liters. Screen is fitted at the intake and outlet thereby having a uniform flow of water at both ways, with a maximum of 4.5 tons per hour. Water

flowing through this compartment is sterilized by ultra violet ray from 2 sets of germicidal lamps installed above. The lamp is 15 watt utilizing 110 a. c. voltage. Table 1, shows its sterilizing capacity.

The water is now conveyed to the purification tank which is 10 meters long, 0.9 meters wide and 0.7 meters high. It is recesivng sterilized sea water through a series of sprinklers individually connected by means of small rubber



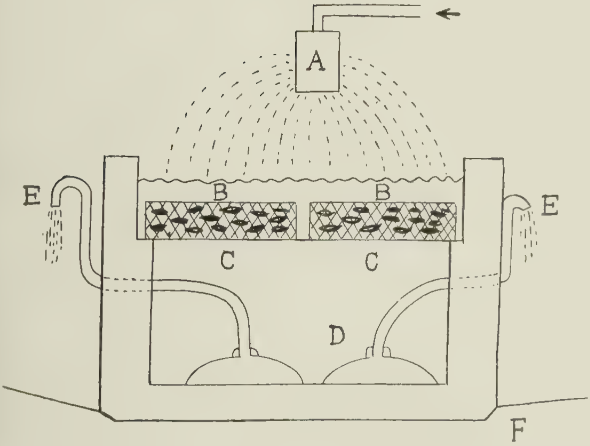
Text-fig. 3. Set up in the purifying room.



Text-fig. 4. Plane figure of a purification plant.
1. Shell washing. 2. Purifying. 3. Sea water sterilizing. 4. Packing room. 5. Tank

Table 1. Efficiency of Germicidal Lamp

Time in second	No. of coligroup bacteria per 100 cc of sea water
0	1,800,000—
15	16,000
30	0
60	0
90	0



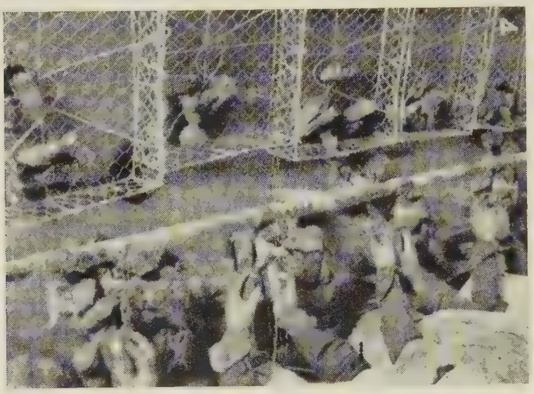
A—Sprinkler
B—Basket with Oysters (C)
D—Porcelain plate
E—Rubber hose
F—Canal for outside drainage

Text-fig. 5. Diagramatic representation of tank drainage

hose from distributing cans to insure uniform supply of water. The level of the water remain constant in the tank and there is a continous slow descending current with the aid of a especial device (Patent no. 217203: 1955), which drains water from the bottom through a siphon fitted with a porcelain plate at the intake with its outlet held at the same level as that of the water in the tank.

Disinfecting Procedure

The first step is to knock off attaching barnacles and other foreign matters on the shell of the oyster. With brush the shell is then cleaning with sea water. (Tex-fig. 6)



Text-fig. 6. Cleaning of the shell.

Oyster is now arranged in plastic basket then subjected to shower of chlorinated sea water (10–20 ppm) for 1 minute.

The above mentioned plastic baskets are then submerged midway into the tank which is supplied with sterilizing sea water. This process last from 12 to 24 hours.

The last step in this sanitation is the wrapping of purified oysters in sulphurized paper before packing in wooden baskets for market.

Relative Discussion

Since purification last for quite a long time, it is possible for the shellfish to get emasipated. As a measure, the mesh of the plankton net use in filtering the sea water prior to sterilization must be large enough till allow passage of minute planktons, of course nutrient substances pass also, so that oyster may take up food during the process.

With that type of set up in the purifying tank, oysters always takes in fresh supply of dissinfected sea water while excreted filths and ferces sink to the bottom with the downward current thereby making the its self-purification more functional.

Oysters are sample from time to time and its M. P. N.[1] determined by A. P. H. A[2] method to see whether purification is going on effectively and to stop it just at the right moment.

[1] Most probable number of coli-group bacteria per 100 cc of sea water or 100 grams of oyster.

[2] American Public Health Association.

Results and Conclusions

From the above stated laboratory works and procedures on the purification of oyster, the following summarized conclusions can be derived:

1. An oyster can live without suffering any of its physiological functions in sea water subjected to ultra violet ray just like in natural environment.

2. The efficiency of purification depends upon the arrangement of the oyster in the tank and the direction of running sterilized sea water. The most satisfactory results can be attained by having a slow vertical descending current and drainage from the bottom, the oysters being midway in the tank.

3. 0.4–0.5 liter of sterilized sea water is sufficient for a 50–60 gram individual. Even oyster contaminated as much as 2,200 M. P. N. will have it dropped to less than 120 in 10 hrs. and 7 after 24 hrs. (Table 2)

4. At 10 degree centegrade, average oyster needs 12–15 hrs. purification. The minimum temperature is still unknown though 8°C still serve the purpose.

Table 2. Efficiency of Purification

Time in hour	0	6	10	24
M. P. N. sea water in tank	0	0	0	0
M. P. N. oyster	2,200	800	120	7
Temp. sea-water C.	8.4	11.0	11.0	10.4
P. H.	8.3	8.3	8.3	8.3

5. At the plant where 3 lines of tanks were equipped, satisfactory purification has achieved upon more than 12,000 of "Single-oyster" every day.

Summary

1. Common edible oysters are highly contaminated in their natural state. Contagious diseases affecting the digestive tract are reported raged through the medium of oyster food.

2. Oyster has the power of self-purification if place in a clean sea water.

3. Purification of oyster can be done artificially by placing them in filtered sea water sterilized by ultra-violet ray, from 12–24 hrs.

Acknowledgement

The author is very grateful to Dr. Y. Toyama and Mr. S. Kawabata, bacteriologist of the National Health Institute, Tokyo for their valuable assistance in perfecting this method of artificial purification of oyster.

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スルメイカ肝油の酸価と色調について

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On the Acid Value and Color of the Liver Oil of Cuttle-fish, *Ommastrephes sloani pacificus*

(*With Text-figs.* 1-4, *Tables* 1-2)

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Résumé

Some reports have been published regarding to the properties of the liver oil of cuttle-fish, *Ommastrephes sloani pacificus*. TSUJIMOTO[3] studied on the some properties of the liver oil; TAKAO et al[5], TSUJINO[6], and YAMADA[7] studied on the constituents of fatty acids of the liver oil. Among the marine oils, cuttle-fish liver oil is generally grouped in the oil with high acid value and dark color. It is said that the quality of the liver oil is to be poor owing to the high acid value and dark color. Since the quality of the liver oil seemed to be affected by the storage condition of the liver oil source, this work was undertaken to find the changes of acid value and color of the liver oil at various storaging conditions of the source, and to find the relation between the acid value and the color. The results obtained were as follows:

1) Acid value of the liver oil and darkness of its color increased with the rise of storage temperature of the source or with the extention of storage time. (Tables 1 and 2)

2) Comparing the liver oil separated from the source which was stored at high temperature with the liver oil separated from the source storaged at low temperature, it is found that the acid values of these liver oils being equal, the color of the former is darker than the one of the latter. (Table 1)

3) As shown in Fig. 1, acid value of the liver oil increases so rapidly in a short time after cuttle-fish was caught that it seems difficult to obtain the liver oil with low acid value (less than 10).

4) It is thought that the darkness of the liver oil might be directly proportional to acid value of the liver oil approximatly. (Figs. 3 and 4)

スルメイカ肝油（以下単にイカ油と記す）が企業的に採取されだしたのは 1945 年頃からで，採油は煎り取り法，自己消化法[1] などにより行なわれたが，当時のイカ油は酸価が極めて高く，色調も濃く，劣等油とされていた[2]。その後採油方法に改良が加えられ，漸次良質のイカ油が得られるようになつて来たが，未だに品質不良のイカ油も少くない。またイカ油の色調が不良な割合に酸価の低いものや，逆に酸価の高い割合に色調が淡色のものも可成り見受けられる。

魚油の酸価，色調は魚油の等級を決定する際の一検査事項となつているが，等級は主に酸価の高低によりきめられ，色調は酸価と正比例するものとみなして等級決定の参考事項として取り扱われている。一般に酸価の高い油脂は色調も濃く品質が悪いものとされているが，同一魚から得られる魚油でも，その酸価並びに色調は魚油の採取方法，原料の鮮度，漁期等の相違によつても異なつてくるといわれている。

イカ油の一般性状については古くは辻本[3]の研究があり，その後大島ら[4]がビタミンAの含有量について検討し，更に近くは高尾ら[5]，辻野[6]，山田[7]が脂肪酸組成について研究している。しかしながらイカ油の生産に関連した一般性状については北林ら[8),9]の研究があるにすぎない。著者は函館地方において相当数のイカ油を取り扱つたが，酸価並びに色調の面からイカ油の品質をみた場合，函館地方という限られた一地域で生産されるイカ油は同一の方法で採取され，しかも油の貯蔵日数にも大差がないにも拘らず，品質に割合大きな差があるように感じた。この原因としてはいろいろのことが考えられるが，スルメイカが漁獲されてから採油までの間における内臓の履歴（ある意味で鮮度）が最も大きく影響するのではなかろうかと思われたので，この点について検討を行い，併せてイカ油の酸価と色調との関係についても考察を加えたのでその結果を次に報告する。

実 験

試 料：

試験に供した市販イカ油は 1950 年 8～10 月の間に採油業者が生産したドラム缶詰のイカ油を適宜に採取した。

実験室で調製したイカ油は 1950 年 9 月から 11 月までの間に漁獲されたスルメイカの内臓から次のごとき方法で得たものである。即ち，内臓 100 部に 100 部の水を加え，撹拌しながら加熱し沸騰させた後，遠心分離して得られた油を無水亡硝で脱水し試料とした。加熱して採取する方法については一応論議のあるところであるが，実際の採油法に近づけるため加熱して試料を調製した。

測 定 法：

酸 価 常法による。

色 調 1/60 M $K_2Cr_2O_7$ 液を標準として Duboscq 比色計で測定し，標準の示す色調を 1 として便宜上試料の色調をあらわした。ただし色調のやや異るもの，標準色との色の濃さが甚だしく異なるものがあるので，その数値の正確度はある程度低い。

全 窒 素 Keldahl 法により測定。

結果並びに考察

1. 内臓放置時間と酸価および色調との関係

1950 年 9 月 22 日に漁獲したスルメイカの内臓を室温に放置した場合，また 1950 年 11 月 2 日に漁獲したスルメイカの内臓を 10°C, 27°C, 43°C に放置した場合の各々について，内臓の放置時間とこれら内臓より得られたイカ油の酸価，色調および窒素含量との関係を検討した結果を示すと Table 1 のようである。表中，放置時間 0 日とあるのは，実験開始時を 0 日とした。Table 1 からも知られるように放置時間が長い程，ま

た高温に放置したもの程酸価が高く，また色調も濃色となる。イカ油の窒素含量も時間の経過と共に増加している。色調の濃淡と窒素含量とは正比例的な関係にあるようだが，これだけのデーターからは断定的なことはいえない。高温に放置した内臓から得られた

Table 1. The variations of acid value, color, and total—N content of the liver oil at various storage conditions of the source.

	Liver oil[1)			Liver oil[2)								
Storage temp.	Room temp. (14～18°C)			10°C			27°C			43°C		
Storage time (days)	A.V.	color	T-N %	A.V.	Color	T-N %	A.V.	Color	T-N %	A.V.	Color	T-N %
0	7.2	25	0.090	7.3	25	0.021	7.3	25	0.021	7.3	25	0.021
1	14.4	32	0.091	10.6	40	0.031	16.0	120	0.027	16.6	130	0.032
2	16.8	56	0.072	12.0	50	0.011	18.5	130	0.034	19.6	280	0.073
4	—	—	—	17.7	70	—	20.6	170	0.050	20.0	360	0.400
5	18.0	105	0.100	18.0	106	—	21.0	260	—	—	420	—
7	19.2	125	0.230	18.8	120	0.029	22.4	380	0.242	28.9	500	0.762

1) The liver oils of this series were separated from viscera of cuttle-fish which was caught in the sea near HAKODATE on Sept. 22, 1950.

2) The liver oils of this series were separated from viscera of cuttle-fish which was caught in the sea near HAKODATE on Nov. 2, 1950.

The liver oil was obtained as below: one part of the viscera was boiled with one part of water and then was centrifuged. The liver oils separated was employed as sample after dehydrating with Na_2SO_4 Anhydrous.

For measuring the color of the liver oil, 1/60 M $K_2Cr_2O_7$ aq. solution was employed as standard color, and the darkness of the standard was defined as 1. The color of the liver oil was measured with Duboscb colorimeter, and the darkness of the color was expressed as the number which was given by comparing the liver oil with the standard color.

イカ油は低温に放置した内臓から得られたイカ油にくらべて酸価の割合に色調は可成り濃くなる傾向にある。即ち得られたイカ油の酸価が同じであつても，採油されるまでに高温に放置した内臓から採取されたイカ油程色調が濃くなることが知られた。

ただここで注意しなければならないことは放置時間 0 日のイカ油の酸価である。漁獲当日の新鮮な内臓を試料としたにもかかわらず，実験開始時に酸価は既に 7 以上もあり，一般魚体油にくらべて可成り高い数値を示している。この原因として考えられることはイカ油は生体中にある時から即ちイカが生きている時から酸価が高いのか，または死後数時間のうちに酸価が高くなるのか，何れかである。

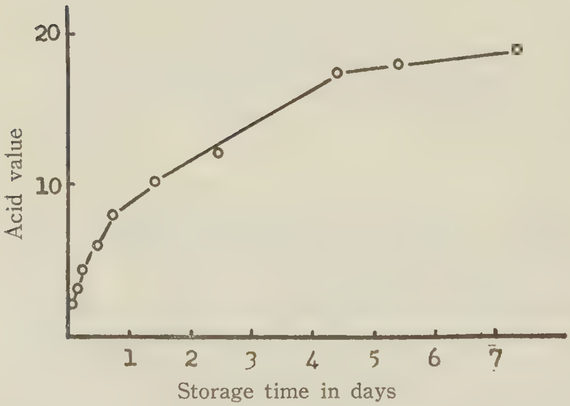
この点を追究するため，漁獲後数時間における酸価の変動を調べてみた。Table 2 は 1950 年 10 月 25 日，および 11 月 5 日の二回にわたつて行つた実験結果である。漁獲直後のイカより内臓をとりだし，この時を 0 時間とし，その後正確に一定時間ごとに内臓から採取したイカ油の酸価と色調並びに窒素含量とを測定したものであるが，採油操作の一部である加熱処理は漁船上で行つたものもある。

この結果から，10月から11月にかけて気温の低い時においても，イカ油の酸価は漁獲後数時間のうちに激しく上昇することが確められた。またイカ油の色調も漸次濃くなることが観察されたが，極めて新鮮な内臓から得られたイカ油でも色調は相当濃いことを知つた。

Table 2. The effect of storage time of the liver oil source on some properties of the liver oil.

	Liver oil[1]			Liver oil[2]		
Storage temp.	Room temp. (13～17°C)			Room temp. (10～15°C)		
Storage time (hrs.)	A.V.	Color	T-N%	A.V.	Color	T-N%
0	1.5	136	0.050	2.4	174	0.036
3	—	—	—	3.0	189	0.040
5	—	—	—	4.4	237	0.038
6	4.0	125	—	—	—	—
8	—	—	—	5.9	233	0.052
12	5.1	150	0.080	—	—	—

1) The liver oils of this series were separated from viscera of cuttle-fish which was caught in the sea near HAKODATE on Oct. 25, 1950.
2) The liver oils of this series were separated from viscera of cuttle-fish which was caught in the sea near HAKODATE on Nov. 5, 1950.
The separation of the liver oil and the measuring method of the color are the same as in Table 1.



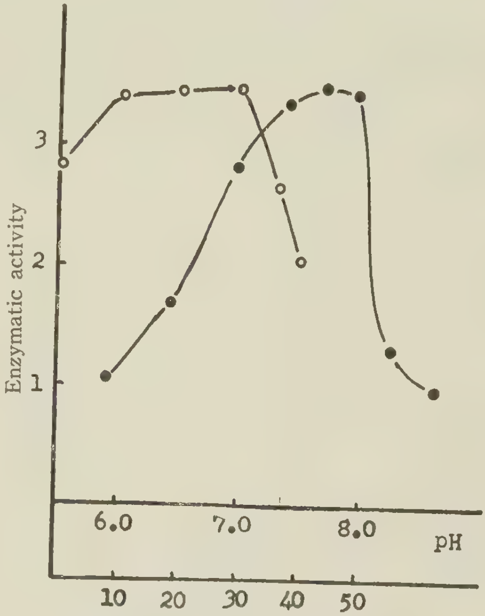
Text-fig. 1. The relation between acid value of the liver oil and the storage time of its source.

実験に使用した試料が一連のものではないが，Table 1 および 2 の結果から 10°C 附近に放置した場合のスルメイカ内臓の放置時間と収得イカ油の酸価との関係を図示するとFig. 1 のような曲線が画かれる。この図で見られるようにイカ油の酸価は内臓の放置時間と共に増加するが，漁獲後 15～18 時間までの間に激しく増大し，酸価 8 位となるが，それ以後は酸価の増加が漸次ゆるやかになる傾向にあつて，24 時間放置した場合に酸価は約 11 となり 4 日後には 17 位まで増加するが，4 日以後は殆んど増加しない。

市販イカ油の大部分はその酸価が 10 以上で，10 以下のものはきわめて少くないが，これは漁獲後 16～18 時間経過した内臓を処理していることに依るものである。今業者が実際に採油する際の漁獲後採油開始に至るまでの経過時間をみると，先ずスルメイカが漁獲されてから陸揚げされるまでの時間は約 8～10 時間である。そして陸揚げされたスルメ

イカはスルメ加工業者により処理され，その際廃棄される内臓は採油業者により集められて始めて採油作業が開始されるが，この間約 8 時間を要している。

多量にスルメイカが漁獲される際には翌日に採油されることも少くなくないが，普通漁獲後16〜18時間後に採油作業が開始される結果となり，Fig. 1 の結果からみてもわかるように作業開始時にはイカ油の酸価は既に 8 以上になつていることになる。今述べたことは秋の漁期を考えた場合であるが，気温の高い夏の漁期においては採油作業開始時にはイカ油の酸価は更に高くなつているはずで，市販イカ油の酸価が 10 以下になり難いのはスルメイカが漁獲されてから十数時間を経て採油していることに依るにほかならない。



Text-fig. 2. The effect of pH or temperature on the enzymatic hydrolysis of tributhyrin by the extract of cuttle-fish liver.

—●— pH-activity curve (hydrolysis at 30°C, 20 hrs.)

—○— temp.—activity curve (hydrolysis at pH 7.8, 20 hrs.)

Original extract was obtained by extracting ground the liver with 5 times weight of 35% glycerol aq. solution, and was used for enzyme solution after diluting with 3 times volume of 1/10 M NaCl aq. solution.

One ml. of enzyme solution was added to the mixture of 5 ml. of phosphate buffer solution and 10 ml. of tributhyrin emulsion, and incubated for 20 hrs. Ten ml. of acetonether mixture was added to the reaction mixture, and was then titrated with 1/10 N alcoholic KOH solution.

Enzyme activity was expressed as ml. of 1/10 N KOH which was used for titration.

2. スルメイカ肝臓のエステラーゼ

上に述べたようにスルメイカ内臓を放置した場合，収得されるイカ油の酸価は短時間のうちに急激に高くなるが，これは主としてスルメイカ肝臓の酵素作用に依るものであろうと考えられるので肝臓抽出液のトリブチリン分解について検討した。

酵素液: スルメイカ肝臓を当重量の海砂と共に磨潰し5倍重量の35%グリセリン水で 30°C において 3 時間抽出し，3000 回転で 10 分間遠心分離した上澄液を酵素液とし，実際使用に当つては 1/10 M 食塩水で 4 倍に稀釈して使用した。

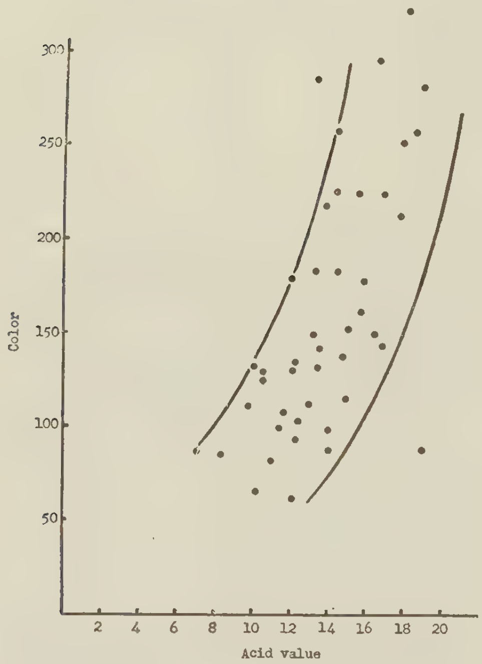
基質乳液: 10%ポリビニールアルコール溶液に，濃度が 1/10 M となるようにトリブチリンを加え（実験化学講座[10]に記載せる方法に従い）調製した。

Activity の測定法: 基質乳液 10 ml に緩衝液（1/15 M 燐酸塩緩衝液）を 5 ml 加え，更に酵素液 1 ml を加えて，手で激しく振つた後，一定時間反応させ，これに 10 ml のアセトン·エーテル混液 (1: 1) を加えて反応を停止させ約 0.25 ml の 10% アルコールフェノールフタレイン液を加え約10分間後に，1/10N アルコール性苛性加里で滴定

る。対照は最初基質乳液を加えずに主実験と同様操作し，アセトン·エーテル混液を加えてから基質乳液を加え，あとは主実験同様に処理した。

スルメイカ肝臓酵素のトリブチリン分解におよぼす pH および温度の影響は Fig. 2 のようである。酵素反応の至適 pH は 7.5～7.8 附近に見られるが，これよりアルカリ側では activity は急激に減少する。また酵素反応の至適温度は 30°C 附近にあつて，30°C より高温では activity は急減するに反し，これより低温においては温度は activity にあまり影響を与えない。10°C 以下では activity はやや低下するが 0°C においても未だ可成りの activity を示している。

函館地方では秋から冬にかけてスルメイカの盛漁期であるが，この間は多忙なためもあるが，気温が低くスルメイカの内臓の鮮度保持が容易であるので，ともすれば採油作業がおくれ勝ちになる。スルメイカ肝臓のエステラーゼは低温においても相当強く作用するものであるから，単に鮮度が保たれているだけの理由で内臓の放置（貯蔵）時間を延長することはイカ油の品質を低下させるのみで，厳に避けなければならない。

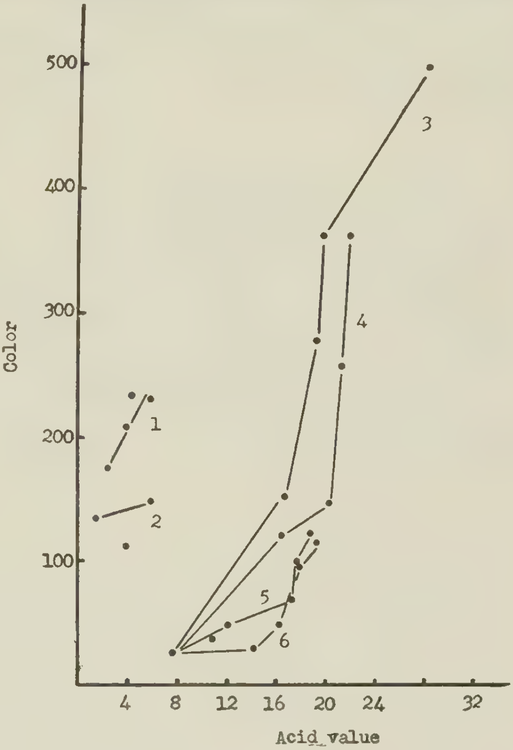


Text-fig. 3. The relation between acid value of the liver oil and its color. (Marketing liver oil of cuttle-fish was employed as a sample.)

3. スルメイカ肝油の酸価と色調との関係

1950 年 8～10 月の間に採油業者が生産したもので貯蔵期間が 1 ヶ月以内と思われる市販イカ油のなかから，数十点を抜き取りイカ油の酸価と色調との関係を検討した。結果は Fig. 3 に示した。また参考のために Table 1 および 2 に示した試験結果に基づいて，酸価と色調との関係を図示したものが Fig. 4 である。Fig. 4 はイカ油の採取時期別に，また試験の条件別に試料の点を大体において結んだものである。Fig. 3 に示した結果をみると，酸価と色調との関係は，ある一つの曲線であらわされるものでなく，ある巾をもつた帯が画かれることを示している。即ち酸価と色調とは，ある巾をもつた範囲内で正比例的な関係にあることが知られる。酸価と色調との関係が線としてでなく，何故帯になつたかを考えてみる。実験室で採取したイカ油は同一時期の内臓で，しかも大部分の試料は同一内臓を種々の条件において酸価の異つた油として得ているものである。従つてこれらのイカ油の酸価と色調は共に内臓の履歴という，いわば二次的な原因のみによつて変化しているものであるから，酸価と色調との関係は Fig. 4 に示すように当然曲線としてあらわされるものである。しかしながら，市販イカ油ではこの二次的な原

因のほかに，内臓自体のオリヂナルな違い（例えば食餌等の違い，北林[8]は季節によるスルメイカの食餌の相違を指摘しているが）も加わり，従つて酸価と色調との関係は，ある巾をもつた帯が画かれるものと思考される。このことは実験室で極めて新鮮な内臓から収得されたイカ油は例外なく酸価は低いけれども，必ずしも淡色でないことからもうなづかれる。今回の実験においてはこの帯の巾の長さについての結論を見出すことはできなかつたが，今まで述べた結果を綜合して考えると，酸価15以下のイカ油の色調の違いは主にオリヂナルな色調の相違に原因があるよであり，そしてまた酸価15以上のイカう油の色調の違いは採油されるまでの内臓の履歴即ち二次的な原因による着色が大きく影響しているように推察される。研究例が少いが Fig. 4 に示した結果はこの傾向をあらわしているように考えられる。



Text-fig. 4. The relation between acid value of the liver oil and its color. (The liver oils were separated from the sources which were stored in the laboratory under various conditions.)

The liver oils of various series were separated from the visceras which were stored under various conditions as described below:

1) Cuttle-fish was caught on Nov. 5, 1950, and its viscera was stored at 10–15°C for 0–8 hrs. (see Table 2)

2) Cuttle-fish was caught on Oct. 25, 1950, and its viscera was stored at 13–17°C for 0–12 hrs. (See Table 2)

3, 4, 5) Cuttle-fish was caught on Nov. 2, 1950, and its viscera was stored for 0–7 days at 43°C in 3), at 27°C in 4), at 10°C in 5). (see Table 1)

6) Cuttle-fish was caught on Sept. 22, 1950, and its viscera was stored at 14–18°C for 0–7 days. (see Table 1)

要　　約

イカ油は一般に酸価が高く色調の濃い油脂とされているが，イカ油の酸価は，スルメイカが漁獲されてから陸揚げされるまでの短時間のうちに，急激に高くなるので，漁獲当日の新鮮な内臓より収得した場合でも，酸価の低いイカ油を得ることが，困難であことを知つた。イカ油の色調はスルメイカが漁獲されてから採油されるまでの間の内臓の放置（貯蔵）条件による二次的な原因のみによつて濃くなるものでない。漁獲直後の内臓から収得したものでも可成り濃色なものもあり，イカ油が濃色であるのはイカ油の固有の性状であろうとも考えられる。しかしながらイカ油の酸価と色調との間には，ある相関々係，即ち，ある巾をもつた範囲内においては正比例的な関係があるように考えられる。そして酸価 15 以下の

イカ油の色調の相違はスルメイカのオリヂナルな色調の相違が大きく影響するようであり酸価 15 以上のイカ油の色調の相違は二次的な原因による着色の相違が大きく関係するものと推察される。

終りに臨み本実験に対し御懇切なる御教授を賜わつた本学立野新光教授に深謝の意を表する次第であります。

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養魚餌料に関する基礎試験—(その 1)

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Fundamental Studies on Fish Farming Food—(I)

(*With Tables 1-7*)

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Résumé

The results obtained from the feeding experiment with guppy *Lebistes reticulatus* were as follows:

(1) The mortality of the fish in the course of this experiment and the breeding activity, fortunately guppy having a short generation, are able to be used as criteria in determining whether or not some foods are suitable for the fish feeding.

(2) Increasing of body weight in every 10 days is assured by augmenting the number of individuals of a lot in the case of such a small sized fish.

(3) The growth of the guppy fed on the foods composed of fish meal, wheat flour and liver of cattle or pig is inferior to that of the species fed on *Limnodrilus*.

養魚餌料に関する研究は古くから数多く行われているが，最近では魚類の要求する種々の栄養素も次第に明らかになつてきた[1]。筆者等も稚魚から親魚までの高密度飼育と急速育成に適した経済的餌料の作製を目的として，基本的には魚類の食性を知るために種々の魚の各生長段階別の消化酵素の種類および強さについて，また新しい餌料原料の探究面ではグルタミン酸醗酵残渣の栄養素等について研究してきた[2,3]。

ところで，従来の養魚餌料の研究は，勝れた人工配合餌料を探し出して直ちに実際の養魚事業に役立てる必要に迫られていたために，主として人工餌料間の比較検討がなされていたようである。そして昆虫類，ミミズ類等の天然餌料が勝れた餌料価値を有することは経験的に知られていても，これらの天然餌料は大量に集めることが困難であるので，天然餌料が人工餌料と比較して，どれ程勝れた価値を有するかといつた問題についてはあまり多くは知られていないように思われる。しかしながら若しこれらの天然餌料が人工餌料と比較して非常に勝れた餌料価値を真に有するものであるならば，その勝れている原因を把握して，その知識をより完全な人工餌料作製のために役立てるような努力がなされねばならないのではあるまいか。

以上のような考えの下で著者等は丈夫で取り扱い易く，その上生長が非常に速い小型熱帯魚グッピー *Lebistes reticulatus* (Peters) を用いる飼育試験によつて，天然餌料と人工餌料との餌料価値を改めて比較検討することにした。

実験 I 乾燥配合餌料によるグッピーの飼育

実 験 方 法

1) 試 料 魚

イトミミズ *Limnodrilus* を与えて飼育した親魚から産まれた仔魚を，生後 20 日間はイトミミズで飼育し，21 日目から供試餌料によつて飼育した。

2) 試験群の編成

3 尾以上の親魚から同日に産まれた仔魚を各出生別に 20 日間飼育し，生後 21 日目の実験開始日に各出生別群からなるべく同数の個体を取出して試験群を編成した。各試験群の構成個体は原則として 15 尾（イトミミズ区のみ 14 尾）とした。

3) 実 験 装 置

1 *l* 容のビーカーを飼育水槽とし，これを大型恒温水槽中に浸して飼育水の温度を 23～25°C に保つた。飼育水には一夜汲み置きした水道水を使用し，隔日に夕方換水した。

4) 乾燥配合餌料の作製

フナ魚粉，小麦粉および豚肝臓を用いて，この 3 原料をすべて揃えたもの，またはそのうちの 1 つを欠くものを第 1 表の配合割合によつて作製した。また魚粉の一部あるいは全

Table 1. Composition of foods—(1).

Number of experiment	Fish meal	Casein	Wheat flour	Starch	Liver of pig
	%	%	%	%	%
1	25.0	—	25.0	—	50.0
2	12.5	12.5	25.0	—	50.0
3	12.5	12.5	12.5	12.5	50.0
4	25.0	—	12.5	12.5	50.0
5	25.0	—	—	25.0	50.0
6	—	25.0	25.0	—	50.0
7	—	25.0	—	25.0	50.0
8	—	—	50.0	—	50.0
9	50.0	—	—	—	50.0
10	50.0	—	50.0	—	—

These foods were heated at 80～90° C for 2 hrs. and used.

部をカゼイン（ビタミン無含有）で置換えたもの，並びに小麦粉の一部あるいは全部を精製馬鈴薯澱粉で置換えたものも作製した。そして，これらを 80～90°C で 2 時間乾燥し，30～50 メッシュに粉砕して乾燥配合餌料とした。この乾燥餌料は冷蔵庫中に保存して，全実験期間を通じて使用した。作製した乾燥配合餌料の成分組成は第 2 表に示した（但し無機物およびビタミン類の含量は分析成書からの推定値である)。

対照に用いるイトミミズは生きたものをそのまま投与した。

5) 投 餌 量

餌量は毎日 8～9 時，12 時前後，15～16 時の 3 回に飽食するまで投与したが，なるべく喰い残しのないように注意した。そして，原則として各体重測定日の前後 3 日間でこのようにして投与した場合の飽食するまでの大約の摂餌量を測定し，3 日間の摂餌量を 3 で

Table 2. Chemical composition of foods.

(per 100 g dry matter)

Number of experiment	Protein	Fat	Carbo-hydrate	Ash	Ca	P	Fe
	g	g	g	g	mg	mg	mg
1	53.0	9.8	33.4	3.8	283	589	469
2	58.4	7.2	31.8	2.6	141	446	231
3	53.9	6.4	37.2	2.5	137	434	225
4	48.6	9.2	38.4	3.8	269	572	447
5	44.3	8.7	43.4	3.6	257	556	436
6	63.5	4.3	30.8	1.4	15	301	13
7	54.7	3.5	40.7	1.1	5	291	13
8	29.2	5.6	63.8	1.4	25	329	14
9	75.9	14.0	3.9	6.2	529	839	889
10	47.1	8.1	41.4	3.4	363	350	585

Number of experiment	Vitamin A	Vitamin B_1	Vitamin B_2	Niacin	Vitamin C
	I.U.	mg	mg	mg	mg
1	8,900	0.5	2.1	19	9
2	8,700	0.4	2.0	17	9
3	8,500	0.4	1.9	16	8
4	8,900	0.5	2.0	19	8
5	8,600	0.5	2.0	20	8
6	8,300	0.3	1.9	14	8
7	7,900	0.3	1.7	13	8
8	8,900	0.4	2.0	15	9
9	9,400	0.6	2.2	23	9
10	600	0.2	0.3	6	0

除して次の体重測定日までの 10 日間に使用する1日当りの投餌量とした。

6） 魚体重測定法

各試験区の全試料魚をガーゼ網で掬つてよく水切りし，予め秤量していた水を入れたビーカー中に移して再び秤量し，両測定値の差を総体重とした。この秤量は化学天秤を用いて mg 単位まで測定し，秤量済みの魚は直ちに元の飼育槽に移して引き続き実験に供した。なお供試魚の雌雄の区別がつけ難く，かつ各試験群中で雌雄による大きさの個体差がさほど目立たない実験開始後 70 日（生後 91 日）までの期間では，総体重を群の構成個体数で除して1尾当りの平均体重を算出した。雄魚の体に斑点が出現し始めるのは早いもので実験開始後 50 日（生後 71 日）目ぐらいからであつたが，実験開始後 80 日になると完全に雌雄を見分けることができた。それで実験開始後 80 日以後は各試験群内で雌魚の総体重と雄魚の総体重とを別々に測定して各々の平均値を算出し，さらにこの2つの平均値を加えて2で除して1尾当りの平均体重とした。即ち同数の雌魚と雄魚とで試験群が構成されているとした場合の1尾当りの平均体重を求めたわけである。

実 験 結 果

乾燥配合餌料によるグッピーの飼育結果は第3表に示した。

Table 3. Feeding experiment with guppy—(1).

A: Average body weight. B: Supplying rate (%/body weight/day)

Number of experiment	1		2		3		4		5		6		7		8		9		10		Control*	
Time of experiment	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B**
day	mg	%	mg	%	mg	%	mg	%	mg	%	mg	%	mg	%	mg	%	mg	%	mg	%	mg	%
0	21	6.4	21	6.4	21	6.1	21	6.4	21	6.4	21	5.7	21	6.4	21	6.3	21	6.4	21	6.4	18	5.2
10	37	6.3	30	6.3	29	5.6	26	5.5	29	6.0	28	5.4	26	5.7	21	6.0	24	6.3	24	5.1	23	5.0
20	51	5.8	39	6.3	39	4.7	37	4.8	40	5.2	39	4.8	34	5.0	22	5.1	27	6.0	27	5.0	33	4.9
30	60	5.2	46	5.5	51	4.2	49	4.4	52	4.5	49	3.6	41	3.7	▲22	—	34	5.7	▲27	—	44	4.5
40	65	4.4	51	4.0	63	3.7	56	4.0	59	4.0	▲52	2.2	▲47	2.4	—	—	41	5.0	—	—	59	4.2
50	66	3.2	53	2.5	69	3.4	61	3.8	62	3.7	▲49	1.9	▲49	1.9	—	—	48	4.0	—	—	76	3.9
60	67	3.1	55	2.4	72	3.3	64	3.6	66	3.4	▲46	2.1	▲48	1.5	—	—	53	3.6	—	—	90	4.0
70	69	3.0	56	2.3	76	3.1	66	3.4	69	3.2	—	—	—	—	—	—	55	3.4	—	—	105	3.9
80	72	2.9	59	2.4	81	3.1	69	3.4	73	3.1	—	—	—	—	—	—	58	3.1	—	—	129	3.5
90	76	2.6	62	2.2	89	3.0	72	3.3	83	3.0	—	—	—	—	—	—	65	3.0	—	—	150	3.2
100	81	2.4	68	2.1	101	2.9	76	3.2	91	2.9	—	—	—	—	—	—	69	2.9	—	—	176	3.0
Relative growth rate***	3.9		3.2		4.8		3.6		4.3		—		—		—		3.3		—		9.8	
Increased body weight/Supplied food****	0.24		0.27		0.26		0.25		0.34		—		—		—		0.32		—		0.59	
Breeding (at)	107th day		—		93rd day		124th day		122nd day		—		—		—		111th day		—		76th day	
♀/♂	9/5		9/5		7/7		7/8		11/4		—		—		—		8/6		—		7/5	

* *Limnodrilus*-supplied group.

** calculated from the dry weight of *Limnodius*.

*** final body weight/initial body weight.

**** $\frac{\text{(total body weight at final + total body weight of dead fishes) − total body weight at initial}}{\text{total weight of supplied food}}$

▲ occurrence of natural death.

フナ魚粉，小麦粉，豚肝臓のすべてを含む試験区および魚粉または小麦粉の一部をそれぞれカゼインまたは馬鈴薯澱粉で置換えた試験区（1〜5 区）並びに小麦粉および澱粉を全く欠く試験区（9 区）ではグッピーは一応生育可能で，これらの試験区の殆んどで仔魚の出産が認められた。しかしながら天然餌料であるイトミミズを投与した試験区(対照区)と比較すると，飼育開始後 30 日以後の生長が急に鈍り，仔魚の出産も遅く，その上これらの乾燥配合餌量の増肉効果は非常に劣つていた。

魚粉を欠く試験区（8 区）ではグッピーは実験開始後 30 日経つても殆んど生長せず，しかもこの頃から斃死魚が表われた。魚粉の代りにカゼインを投与した試験区（6, 7 区）では実験開始後 40 日頃までは魚粉を含む試験区とほぼ同程度の生長を示したが，それ以後の生長が急に鈍り，かつこの頃から斃死魚が表われた。

肝臓を欠く試験区（10 区）ではグッピーは殆んど生長することができず，実験開始後 30 日頃から斃死魚が続出した。

実験 II　生配合餌料によるグッピーの飼育

乾燥配合餌量で飼育したグッピーはイトミミズで飼育したものと比較して，最初のうちは良好な生長を示したが，飼育開始後 30 日以後の生長が急に鈍つてきた。そこで次にいわゆるH因子を充分含み，しかも度々作製し直して餌料成分の保存中における悪変化を防いだ生配合餌料での飼育を行つた。

実験方法

1）　生配合餌料の作製

フナ魚粉と牛肝臓とを第 4 表に示した割合に配合したものを予め適当量の水を加えて煮

Table 4. Composition of foods—(2).

Number of experiment	Fish meal	Wheat flour	Liver of cattle	Water
	g	g	g	g
11	—	20	100	—
12	8	20	75	17
13	16	20	50	33
14	24	20	20	43
15	28	20	13	49

沸していた小麦粉で練つて使用した。この時作製餌料の水分を一定にするために小麦粉に加える水量を加減した。作製した生配合餌料は冷蔵庫中に保存し，10〜15日ごとに新しく作製し直した。

2）　飼育水の換水

毎日夕方に行つた。

3）　その他

その他の実験方法は実験 I に準拠した。

実験結果

生配合餌料での飼育結果は第 5 表に示したが，これらの餌料で飼育されたグッピーは乾

Table 5. Feeding experiment with guppy—(2).

Number of experiment	11	12	13	14	15	Control*
Time of experiment	Average body weight					
day	mg	mg	mg	mg	mg	mg
0	15	15	15	15	15	18
10	20	21	20	20	19	23
20	29	27	27	26	24	33
30	36	38	34	31	27	44
40	43	46	37	35	31	59
50	46	51	39	37	33	76
60	49	53	41	38	34	90
70	51	55	43	41	34	105
80	52	56	45	43	35	129
Relative growth rate	3.5	3.7	3.0	2.9	2.3	7.2

* *Limnodrilus*—supplied group.

燥配合餌料で飼育されたものと殆んど同程度の生長を示すだけで，イトミミズ投与区の生長よりは非常に劣つていた。そしてやはり実験開始後 30 日以後の生長が急に鈍るのが観察された。

実験 III　合成餌料でのグッピーの飼育

以上 2 つの実験で一応配合餌料によつてグッピーを飼育できたので，グッピーの飼育をビタミン類等の栄養試験に応用できないかと考えて最後に合成餌料による飼育を行つた。

Table 6. Composition of foods—(3).

	g		mg
Casein	25	Vitamin B_1	0.15
Starch	10	〃 B_2	0.44
Olieve oil	5	〃 B_6	0.25
Salts	10	〃 B_{12}	1.05
Water	50	Biotin	0.04
		Panthotenic acid	0.97
	mg	Inositol	1.00
NaCl	0.44	Folic acid	0.03
$NaH_2PO_4 \cdot H_2O$	0.87	Niacin	3.00
K_2HPO_4	2.44	Choline	5.00
$CaH_4(PO_4)_2 \cdot H_2O$	1.35	Vitamin A	100 I.U.
$Fe(C_6H_5O_7)$	0.30	〃 C	0.55
$Ca(C_3H_5O_3)_2$	3.25	〃 D	0.10 I.U.
$MgSO_4$	0.67	〃 E	1.00
KI	0.08		

実 験 方 法

1)　合成餌料の作製

第6表に示した原料を用いて蛋白質，脂肪，炭水化物，無機物およびビタミン類をすべて含む餌料と全ビタミン類のみを欠く餌料とを作製した。

2)　そ の 他

その他の実験方法は実験 II に準拠した。

実 験 結 果

合成餌料による飼育ではビタミン類を含むと含まないとに拘わらず摂餌量は極めて僅かで，生長は殆んど認められなかつたので，実験期間を通じての生存尾数のみを第7表に示した。この合成餌料では実験開始後10日頃から斃死魚が続出し，30日で約半数が斃死してしまつた。

Table 7. Feeding experiment with guppy—(3).

Time of experiment (day)		0	10	20	30	40
Number of survival	Vitamin supplied group	13	13	11	9	8
	No vitamin group	13	12	9	7	6

考　　察

グッピーを用いる飼育試験では供試餌料で仔魚を出産するまで魚を飼育し，仔魚出産の有無および飼育期間中の斃死魚の有無を観察すれば，供試餌料が一応魚に対して使用できるか否かを判定することが容易であつた。そしてこの飼育試験は魚の生長度を追跡する場合にも適用できて，餌料価値の勝れたものと劣るものとを明らかに知ることができた。しかし一つの試験区内での個体生長差が案外大きかつたので，生長度を追跡する場合には一試験区を構成する個体数をもつと多くする必要があると思われた。

フナ魚粉，小麦粉および牛または豚肝臓を原料として作製した乾燥配合餌料あるいは生配合餌料でも一応グッピーを飼育できたが，天然餌料であるイトミミズと比較するとこれらの配合餌料は約半分の増肉効果しか示さず，その餌料価値はより劣るものと判断せざるを得なかつた。これらの配合餌料で飼育した群ではある一部の個体はイトミミズで飼育したものと大差のないほどよく生長したが，その他の大部分の個体の生長は悪くて，一つの群中での生長個体差が大きいことが目立つた。これに反しイトミミズで飼育した群中の個体は比較的揃つてよく生長したので，この差が両試験区の平均体重の差並びに増肉効果の差となつて表われたのではなかろうか。(イトミミズによる飼育試験は繰返して実施したが，ほぼ前回と同程度の体重増加を示し，各個体とも揃つてよく生長することが認められた。)

一般に魚の1日の摂餌量は体重当りで計算した場合生長すると共に次第に減少してくるが，第3表の乾燥配合餌料区の投餌量の減少度はイトミミズ区の減少度よりも大きい。この投餌量は魚が飽食するまでの大約の摂餌量から計算したものであるが，投餌した際の餌

料に対する魚の行動を観察していると配合餌料とイトミミズとでの真の摂餌量には第3表の価よりももつと大きな差があるように感じられた。生後イトミミズで 20 日間飼育した魚に 21 日目にイトミミズを与えると直ちに摂餌するのは勿論であるが，乾燥または生配合餌料では約1日後から摂餌し始め，合成餌料では約3日後でなければ摂餌しなかつた。なお生後 21 日目から配合餌料に切換えて100日間を経過した群中に，その配合餌料と摺り潰したイトミミズとを同時に投与すると，群中の大部分の個体がイトミミズを摂餌しようとする行動を起して，配合餌料はイトミミズがなくなるまで摂餌しなかつた。このようなことから配合餌料とイトミミズとでは魚の嗜好する成分の種類あるいはその含量に大きな差があつて，その他の色々な要因と共にこの成分が餌料の価値に大きく影響しているように感じられた。

摘　　　要

グッピーを用いての飼育試験によつて人工配合餌料とイトミミズとの餌料価値を比較して次の結果を得た。

1)　グッピーは仔魚を産出するまでに要する期間が非常に短いので仔魚産出の可否，並びに飼育期間中での斃死魚の有無によつて，ある餌料が魚類に適用できるかどうかを判定することは容易であつた。

2)　飼育期間中の生長度を測定することも試験区を構成する個体数を多くすることによつて可能であり，魚の生長比または餌料の増肉効果を確めることも可能であつた。

3)　魚粉，小麦粉，家畜肝臓を主原料とした人工餌料の増肉効果はイトミミズのものより非常に劣つていて，人工餌料を改善する必要があることを痛感した。

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養鰻池の水変りに関する研究—XIX

養鰻池のプランクトンに対する海水注入の影響

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Studies on the "Mizukawari" in Eel-Culture Ponds—XIX

The Effect of the Sea Water Supply upon the Plankton in Mixohaline Eel-Culture Pond

(*With 3 Text-figures*)

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Résumé

It is sometimes necessary to supply a large quantity of sea water into the eel-culture pond to control *Lernaea*, the parasite of the cultured eels there. This study, aiming to make clear the influence of the sea water supply on the plankton, the water quality and on the feeding activity of the cultured eels and to find what the relation is between the sea water supply and "Mizukawari", has been carried out in a mixohaline eel-culture pond (area 46 a, depth 1 m) in Tsu City, Mie Prefecture, Middle Japan.

Through the sea water supply in the period Sept. 13–17, the salinity of the pond water showed the sudden increase from Cl 2.3‰ to 5.3‰. Further, by the supply of groundwater it decreased to Cl 3‰. The supply of sea water has caused the perishments of freshwater phytoplankters, *Chroococcus minutus*, *Merismopedia tenuissima*, *Microcystis aeruginosa*, and *Scenedesmus quadricauda*. But no influence was observed at all on *Chroococcus dispersus*, *Ch. limneticus*, *Dactylococcopsis rhaphidioides*, *Nitzschia closterium* and *Cyclotella glomerata*. After the supply of sea water, *Chaetoceros Muelleri* and *Euglena* sp. were found considerably increased. On the other side, *Microcystis aeruginosa*, once seemed to have perished, re-appeared to be observed when the salinity lessened to Cl 3‰ (Fig. 1).

No effects of the sea water supply were observed on such mixohaline zooplankters as *Pseudodiaptomus inopinus*, *Brachionus plicatilis* and *Hexarthra fennica*, but some freshwater zooplankters as *Moina dubia* and *Br. calyciflorus* f. *amphiceros* were found perished. The latter two species, however, reappeared when the salinity was down to Cl 3‰, as *Microcystis aeruginosa* did. The two species, *Br. quadridentatus* var. *clunioribicularis* and *Br. angularis*, showed considerable increase in spite of the sea water supply (Fig. 2).

The water color of the pond, after the supply of sea water, has changed in the order from green, brown, dark brown to bluish green; this change of water color is caused by that of plankton flora there. At that time, the transparency rose from 20 cm to 47 cm, pH lowered from 9.0 to 7.3, and dissolved oxygen decreased from 6.8 cc/l to 2.4 cc/l., NH_4-N and NO_2-N have also remarkably increased

after the sea water supply (Fig. 3).

The feeding activity of the cultured eels much more weakened, but such an extraordinary phenomenon as surfacing was not observed at all.

Consequently, it can be said here that through the sudden supply of sea water, part of freshwater algae shows perished, the dissolved oxygen decreases, a kind of "Mizukawari" phenomenon is observed; but even in that case no damage is observed on the cultured eels.

1 まえがき

養鰻池は海岸地帯にあり，池水は可成りの塩分を含有し，殆んど"汽水"に属する。それらのプランクトン相は池水の塩分によつて異るが[1),2)]，構成要素は淡水産並びに汽水産である。このような養鰻池において，イカリムシ防除のために，大量の海水を注入する場合がある。海水注入によつて，そこに棲息していたプランクトンがどのような影響を受けるか，また水質，養殖魚の摂餌量等はどのように変化するか等を知ることは，陸水学的にも興味深い問題であるのみでなく，海水注入と水変りとの関連，プランクトンと塩分変化との関係を見究める上にも極めて重要な事柄である。しかし海水注入の影響の実態については不明の点が多い。

筆者等はイカリムシ防除のために海水を注入された1養鰻池において，注水前後における水質，プランクトン相の変化を観測する機会を得たので，その実態について報告したい。

本研究にあたり観測上種々の便宜を与えられた池の所有者黒宮正郎氏，並びに野外観測に協力された本学水産学部増殖学科学生新二郎君に謝意を表します。

2 観測方法

観測は津市島崎町黒宮養魚場第2号養鰻池（M_2 池と略称）で行つた。この池は志登茂川下流南岸に膚接し，面積 46a，水深約 1 m，海水注入前の池水の塩分 Cl 1.7～2.3‰ で，貧鹹性汽水[3)]に属する。昭和 31 年 9 月上旬からイカリムシの寄生が認められたので，その防除のために，満潮時に，9 月 13 日から 17 日にわたり，水門を開いて海水を注入した。その間塩分分布を均一にするために水車をかけた。その後約 10 日間放置し，27 日から地下水を注入し，塩分を再び下げた。

観測並びに水質分析の方法，プランクトンの定量法は第 12 報[4)]と同じである。

3 観測結果

a 植物プランクトン (Fig. 1)

9 月 13～17 日の海水注入によつて，池水の塩分は Cl 2.3‰ から急激に増大し，最大 5.3‰ に達した。その後 9 月 27 日からの地下水の注入により，塩分は徐々に低下し，10 月 15 日には Cl 3‰ 近くに低下した。

海水注入前後における植物プランクトン相の変化は，Fig. 1 に明かのように，*Chroococcus minutus*, *Merismopedia tenuissima*, *Microcystis aeruginosa* 等の淡水産藍藻類，並びに *Scenedesmus quadricauda* は Cl 3.9～5.3‰ の塩分には殆んど消滅した。しかし *Chroococcus dispersus*, *Ch. limneticus*, *Dactylococcopsis rhaphidioides*, *Oocystis* sp., *Nitzschia closterium*, *Cyclotella glomerata* 等には影響は見られていな

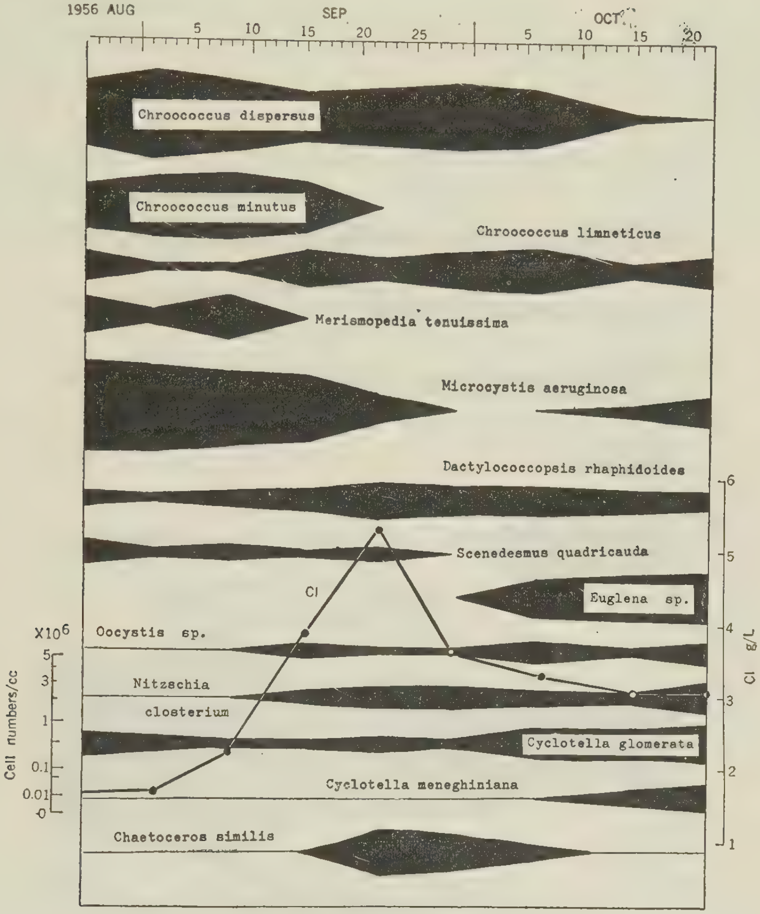

Fig. 1. The effects of sea water supply upon the phytoplankters in an eel-culture pond of brackish water, Tsu City, Mie Prefecture.

い。海水注入後に著しい増殖の見られたのは，*Chaetoceros similis* と *Euglena* sp. である。前者は Cl 3.9～5.3‰ で最も増殖し，10 月 8 日頃には殆んど消滅した。海水注入後，池水が褐色乃至暗褐色を呈したのは，この硅藻の大増殖に由来すると考える。*Euglena* sp. は *Chaetoceros similis* が著しく減少した頃から増殖しはじめ，10 月上旬から中旬にかけて，池水が青緑色を帯びたのは，この藻類の大増殖によるものである。

地下水注入による低鹹化に伴い，一旦消滅した *Microcystis aeruginosa* は Cl 3‰ に低下した 10 月 15 日頃から再び増殖した。

b 動物プランクトン (Fig. 2)

汽水系の動物プランクトン，例えば，橈脚類の *Pseudodiaptomus inopinus*, *Paracyclopina nana*, それらの nauplius, 輪虫類の *Brachionus plicatilis*, *Hexarthra fennica* 等は海水注入の影響を受けていない。しかし淡水産の 1 部，即ち枝角類の *Moina dubia*, 輪虫類の *Barchionus calyciflourus* f. *amphiceros* 等は海水注入により，Cl

3.9‰ 以上の塩分では殆んど消滅した。しかし，この両種は地下水注入によつて Cl 3‰ 前後に低下した頃から再び出現している。この状態は藍藻の *Microcytic aeruginosa* のそれに酷似する。

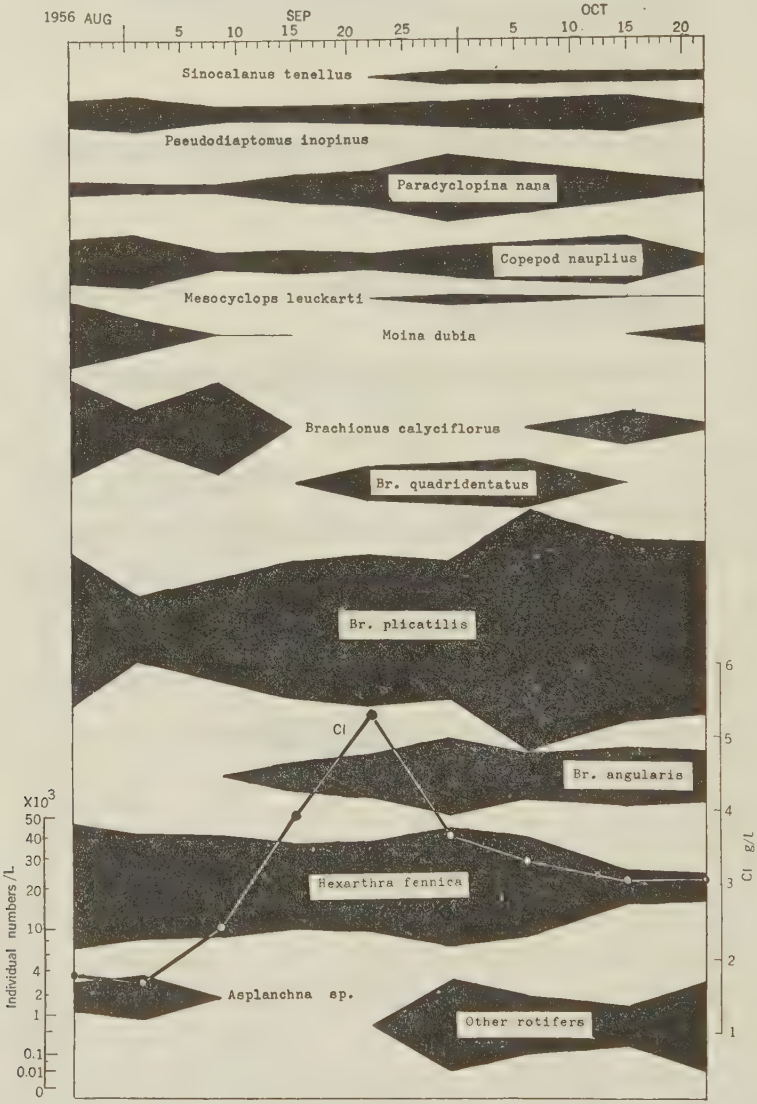

Fig. 2. The effects of sea water supply upon the zooplankters in an eel-culture pond of brackish water, Tsu City, Mie Prefecture.

海水注入によつて特に注目すべき動きを示したのは，淡水産輪虫の *Br. quadridentatus* var. *cluniorbicularis* 並びに *Br. angularis* s. str. である。両種は *Br. calyciflorus* の消滅時から出現し，最大塩分 (Cl 5.3‰) にも影響されず増殖した。

c　池水の水質 (Fig. 3)

海水注入の前後における池水の水質の変化は Fig. 3 に示した。池水の水色は海水注入

によつて，緑色→褐色→暗褐色→青緑色の順に変化した。この変化系列は，海水注入前後における植物プランクトン相の変化が最も大きく作用していると考える。即ち海水注入前には，*Chroococcus*, *Merismopedia*, *Microcystis* が卓越し，池水は深緑色を呈していたが，海水注入によつてこれらの多くが消滅し，硅藻の *Nitzschia closterium*, *Chaetoceros similis* が著しく増殖し，そのために池水は褐色乃至暗褐色系が強くなり，その後青緑色に変化したのは *Euglena* sp. の植物色によることは明かである。池水の透明度も植物プランクトンの変化に伴つて変化した。海水注入前は 20 cm 前後であつたが，

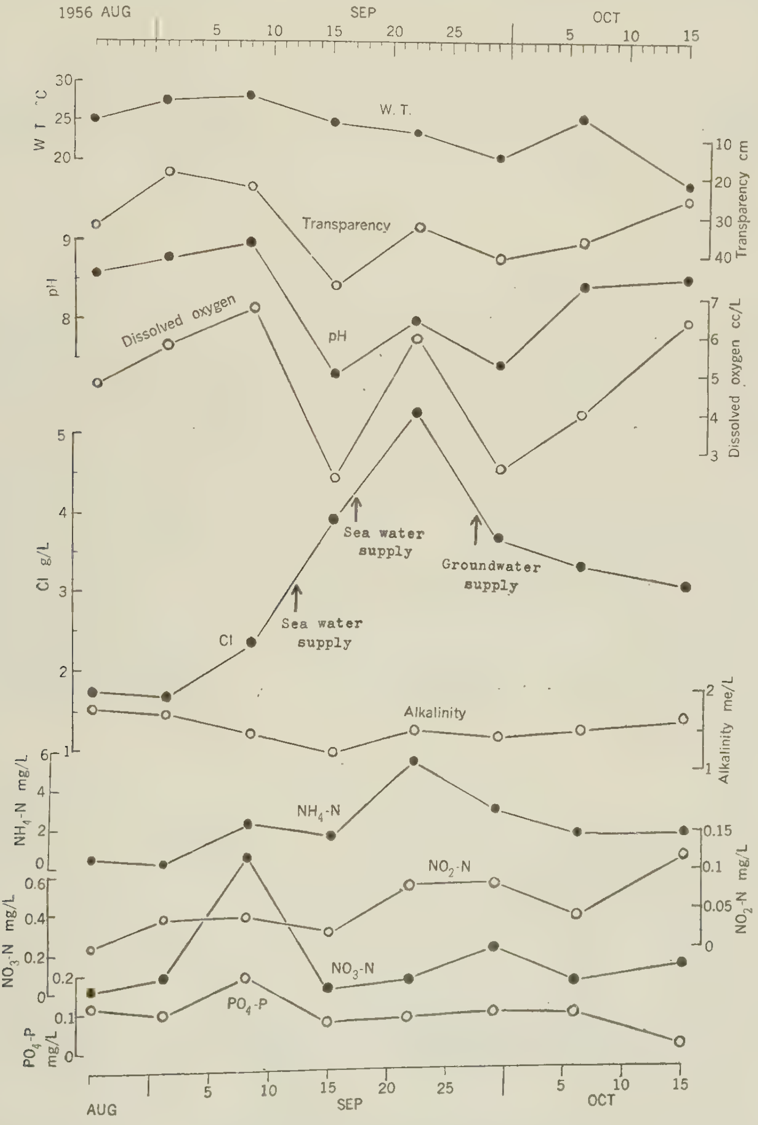

Fig. 3. The effect of sea water supply upon the water quality of an eel-culture pond, Tsu City, Mie Prefecture.

海水注入につつて透明度は急激に増大し, 47 cm を示した。しかし塩分の最大時に透明度は却つて 30 cm に低下したが, これは前述の *Chaetoceros similis* の増殖に原因すると考える。これは池水の pH, 溶存酸素にも表われている。池水の pH, 溶存酸素も海水注入によつて著しい低下が見られる。即ち pH は 9 から 7.3 に, 溶存酸素は 6.8 cc/*l* から 2.4 cc/*l* に夫々低下した。しかし塩分の最高時に pH, 溶存酸素が 1 時的に上昇しているのは, *Chaetoceros similis* の増殖に起因することは前述した。アルカリ度には著しい変化は見られていない。NH_4–N, NO_2–N は海水注入後に顕著に増加しているが, NO_3–N, PO_4–P には却つて減少が見られた。

d　養殖魚の状態

当時イカリムシ寄生のために, ウナギの摂餌量は良好でなかつたので, 餌付に対する海水注入の影響は明瞭ではなかつたが, 海水注入後から 9 月末にかけて餌付は更に悪化した。しかし早朝の鼻上げ等の異常現象は見られなかつた。餌付は 10 月上旬からやや好転した。

4　考　　察

養鰻池においては, 海水注入によつても, 淡水系植物プランクトンの一部が消滅し, 池水は緑色から褐色系に変化し, 透明度も著しく増大し, かつ池水の pH, 溶存酸素も顕著に低下し, NH_4–N, NO_2–N 等も著しく増加することが, 津市北部の M_2 池における本観測の結果明かになつた。この現象は, 動物プランクトンの異常増殖を伴つた水変り[5)6)7)8)9)10)11)]と, 現象面からは類似している。従つて大量の海水注入によつても水変り類似の現象がおこるといえるが, この場合の水変りの程度は, 動物プランクトンの大増殖による水変りに比べて, 極めて軽微であるといえよう。この海水注入による水変り現象は, 注水前の池水の塩分並びにプランクトン相, 注水量並びに注水速度等によつて, その様相および程度は当然異るであろう。またこの現象は塩分変化による植物プランクトンの急激な斃死, 機能低下, 並びに植物プランクトンの稀釈化等が主な原因をなし, 海水注入の影響は全般的には, 池水の塩分が Cl 5‰ をこえる場合に顕著に大きくなる可能性が, 養鰻池のプランクトンと塩分との関係[1)2)12)13)]から考えられる。

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養鰻池の水変りに関する研究—XX.

養鰻池のプランクトン相に対する冬期池替の影響並びに池替後におけるプランクトン相の形成

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Studies on the "Mizukawari" in Eel-Culture Ponds—XX.

The Effect of Winter Drainage upon the Plankton and Formation of the Plankton Community after the Water-Renewal in Eel-Culture Ponds

(*With* 19 *Text-figures and* 4 *Tables*)

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Résumé

In all eel-culture ponds, every pond is dried up in the winter season, the eels gathered, sometimes some bottom mud mucked out, and after that it is refilled with groundwater, surface water or the old water from other ponds; this is called "Ikegaè" (water-renewal). By that winter "Ikegaè", what changes will be brought in the water quality and the plankton? After the "Ikegaè", how will go the formation of the plankton community? And when will come the first "Mizukawari"? To resolve these problems, this research was made in six eel-culture ponds in Tsu City, Mie Prefecture, in the period, Dec., 1956 to June, 1957.

The conditions for the water-renewal are shown in Table 1. With such various conditions for the water-renewal as mentioned, the following conclusions can be deduced.

The dominant species of phytoplankton in the winter time are the micron alga as *Synechococcus* sp., *Chroococcus dispersus*, *Selenastrum gracile* and *Chaetoceros Muelleri*; and those of the zooplankton are represented by the copepods as *Sinocalanus tenellus*, *Pseudodiaptomus inopinus* and *Paracyclopina nana*; and by the ciliates as *Didinium* sp., *Paramecium* sp. and *Strobilidium* sp.

After the water-renewal, in phytoplankton, the dominant species before show a remarkable increase within a week, and in zooplankton, no conspicuous difference was found with the water-renewal. The succession of zooplankton in each pond after the water-renewal is quite in accordance with those of other ponds.

Consequently, it can be said that the water-renewal in the winter time brings little or no effects upon the plankton in the eel-culture ponds.

The seasonal seccessions of plankton rotifers in these eel-culture ponds are as follows:

Unknown rotifer (Feb.—Mar.)—*Keratella cruciformis* var. *eichwaldi* (Apr.—

*) 現在は三重県水産試験場伊勢湾分場

May) — *Brachionus quadridentatus* (or *Br. urceolaris*; May) — *Br. plicatilis*; (May or Jun.—Dec.).

And the above rotifers cause the "Mizukawari". The degree of "Mizukawari" by the former two rotifers are quite trifle, but those by the latter two are very serious.

I. は じ め に

養鰻池では一般に冬期に全池水を排水し，ウナギを取り揚げると共に，ときには底泥を取り除き，地下水，地表水，あるいは他の池水等で湛水する。これは"池替"と呼ばれている。池替によつて池水の水質，プランクトンはどのように変化するか。また池替後にプランクトン相はどのように形成され，水がどのようにできていくかを知ることは，陸水学的に興味深い問題であるのみでなく，実際の池水管理上にも極めて重要なことである。しかし，これらの点については不明のことが多く，また養鰻池の冬期のプランクトン相に対する吾々の知識も極めて貧弱である。そこで筆者等は，1) 冬期養鰻池のプランクトン相の特異性．2) 池替によるプランクトン相の変化．3) 池替後における"水の出来"とプランクトン相の形成 4) 水変りのはじまる時期等を明かにするために，昭和 31 年 12 月から 32 年 6 月にわたり，津市北部の養鰻池群において観測を行つた。その結果を報告したい。

本研究にあたり，観測上種々の便宜を与えられた池の所有者黒宮正郎・加藤慎太郎・大橋房男氏に深甚の謝意を表します。

II. 観測池群の概況並びに観測方法

観測は津市北部の養鰻池群，即ち黒宮養魚場第 1・第 2・第 4・第 7 号養鰻池 (M_1・M_2・M_4・M_7 池と略称する)，加藤養魚場第 2 号養鰻池 (K_2 池と略称)，大橋養魚場第 1 号養鰻池 (O_1 池と略称) の 6 面の養鰻池で実施した。(Fig. 1)

これらの 6 面の養鰻池群における池替の時期および期間，底泥の処理，湛水用の源水の種類並びに割合，池替前・後における池水の塩分は Table 1 に示した。池替の時期は 1 月上旬から 4 月上旬にわたり，底泥処理も浮泥を除去したもの，全く除去しないものもあり，かつその後の湛水に使用した源水も池によつて異つている。これらの養鰻池群は底泥処理，池替後に湛水した源水の種類によつて，次の 3 群に分けられる。

1. 底泥を除去せず，地下水のみで湛水。
   - i) 1 月に池替，M_2 池，M_4 池
   - ii) 3 月に池替 M_7 池
2. 底泥を除去せず，地下水と他池水で湛水，M_1 池 (1〜2月に池替)
3. 底泥を除去し，地下水と他の池水で湛水，K_2 池，O_1 池 (共に 2〜3 月に池替)

観測は，M_1・M_2・M_4・M_7 池では昭和 32 年 1 月 19 日から 4 月 10 日にわたり，K_2・O_1 池では昭和 31 年 11 月 20 日から昭和 32 年 6 月 24 日にわたり，いずれも約 1 週間間隔に行い，観測時刻は午前 10〜11 時，池水の水質分析，プランクトンの定量は各池の 1 定点において表層水について行つた。水質の分析方法，観測方法，並びに植物プランクトン，動

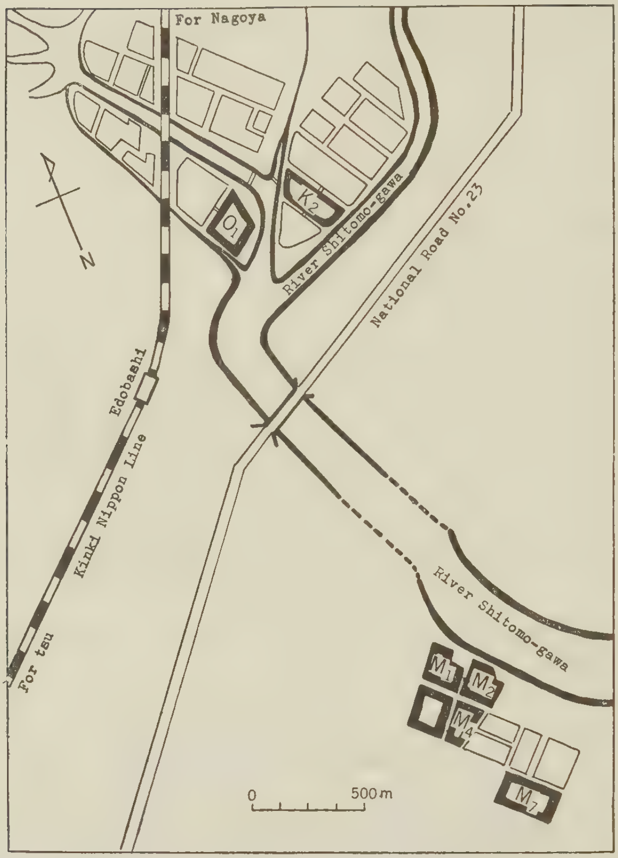

Fig. 1. Map showing the eel-culture ponds in the northern part of Tsu City, Mie Prefecture, Middle Japan. M_1, M_2, M_4, M_7, K_2 and O_1 show the ponds where various surveys were made.

Table 1. The conditions of water-renewal (Ikegaè) in six eel-culture ponds in the northern part of Tsu City, Mie Prefecture, Middle Japan.

*) groundwater; **) old pond water.

Ponds	Period of "Ikegaè"	Water sources after "Ikegaè"	Treat-ments of bottom mud	Chlorinity of water ‰	
				Before "Ikegaè"	After "Ikegaè"
M_2	Jan. 14-18, '57	groundwater	removal	—	1.8-3.9
M_4	Jan. 4-13	groundwater	,,	—	1.9-5.3
M_7	Mar. 26-Apr. 2	groundwater	,,	6.7-7.9	5.8-6.3
M_1	Jan. 25-Feb. 9	g. w.* (30%) + p. w.** (70%)	,,	2.6-2.7	1.9-3.5
K_2	Feb. 13-Mar. 5	g. w. (50%) + p. w. (50%)	no removal	1.8-6.0	3.1-5.5
O_1	Feb. 13-Mar. 14	g. w. (50%) + p. w. (50%)	,,	1.9-4.9	2.5-4.8

物プランクトンの定量方法は第8報[1]，第12報[2]と同じである。プランクトンの定量結果は，すべて Lohmann の球曲線法を用いて図示した。

III. 観 測 結 果

1. 底泥を除去せず，地下水のみで湛水した場合

M_2 池 (Figs. 2〜4)

1月14日から2日間で全池水を排水し，底泥は除去せず，2日間池底を干した。18日から地下水のみの注水をはじめ，4日後の22日に満水した。注入地下水の水質の分析結果は Table 2 に示した。

Table 2. The water quality of the groundwater used for the water sources of the eel-culture ponds, M_1, M_2 and M_4.

Elements	Date 1957					
	Jan. 19	Jan. 21	Jan. 25	Jan. 29	Feb. 5	Feb. 20
Time	13.25	10.05	10.30	10.15	9.45	9.35
A. T. °C	7.2	7.5	6.3	8.8	12.5	5.8
W. T. °C	16.1	16.0	16.3	16.2	16.5	16.1
Water colour	clear	〃	〃	〃	〃	〃
pH	7.0	7.0	7.0	7.0	7.0	7.1
Dissolved oxygen cc/*l*	1.98	1.99	1.81	1.70	1.63	2.21
%	29	29	26	25	24	32
Transparency	—	—	—	—	—	—
Alkalinity me/*l*	2.55	2.50	3.11	2.48	2.51	2.63
Cl g/*l*	1.48	1.48	1.92	1.48	1.54	1.52
SiO_2 mg/*l*	28.1	22.4	22.2	29.4	27.8	18.8
NH_4-N mg/*l*	0.85	1.18	1.25	1.14	0.95	1.14
NO_3-N mg/*l*	0.01	0.02	0.01	0.01	0.004	0.01
NO_2-N mg/*l*	tr.	tr.	tr.	tr.	tr.	tr.
PO_4-P mg/*l*	0.037	0.074	0.050	0.089	0.074	0.097
Fe mg/*l*	2.86	1.71	2.50	4.29	4.00	4.29

満水して2日後には，透明度は20 cm，溶存酸素は10 cc/*l* 以上，pH は 9.7 となつた。池水の Fe は地下水注入のために満水後7日間位は多く，約3 mg/*l* を示したが，その後徐々に減少した。Alkalinity, SiO_2, NH_4-N は湛水後徐々に減少し，PO_4-P は逆に増加しているが，NO_3-N, NO_2-N 等には著しい変化は見られない。2月20日過ぎから3月10日にわたり，池水の透明度は増大しているが，これは輪虫の増殖に一致している。(Fig. 2).

植物プランクトンは満水時から，優占種は *Synechococcus* sp., 次いで *Chaetoceros Muelleri* が卓越していたが，3月下旬に *Synechococcus* は消滅し，それに代つて，*Chroococcus dispersus* が優占種となつた (Fig. 3)。

動物プランクトンとしては，*Paracyclopina nana* が2月中旬から，*Sinocalanus tenellus* は3月上旬から出現し，特に種名不詳の輪虫が2月中旬から大増殖し，4月上旬には殆んど消滅した。汽水性輪虫の *Keratella cruciformis* var. *eichwaldi* は3月中旬

から出現し，大増殖をはじめた。その他，繊毛虫類の *Strobilidium* sp., *Paramecium* sp., *Didinium* sp. の卓越が著しい (Fig. 4)。

プランクトン相に対する池替の影響は，満水後から観測を実施したので明かでない。

M_4 池 (Figs. 5～7)

1月4日に池替をはじめ，2日後に排水を完了，底泥はそのままで2日間池干。1月8日から地下水 (M_2 池のそれと同じ) を注入し，13日に満水した。

満水後における水質の変化，植物プランクトン並びに動物プランクトンの遷移は，Figs. 5～7 に明かのように，前述した M_2 池のそれによく一致している。

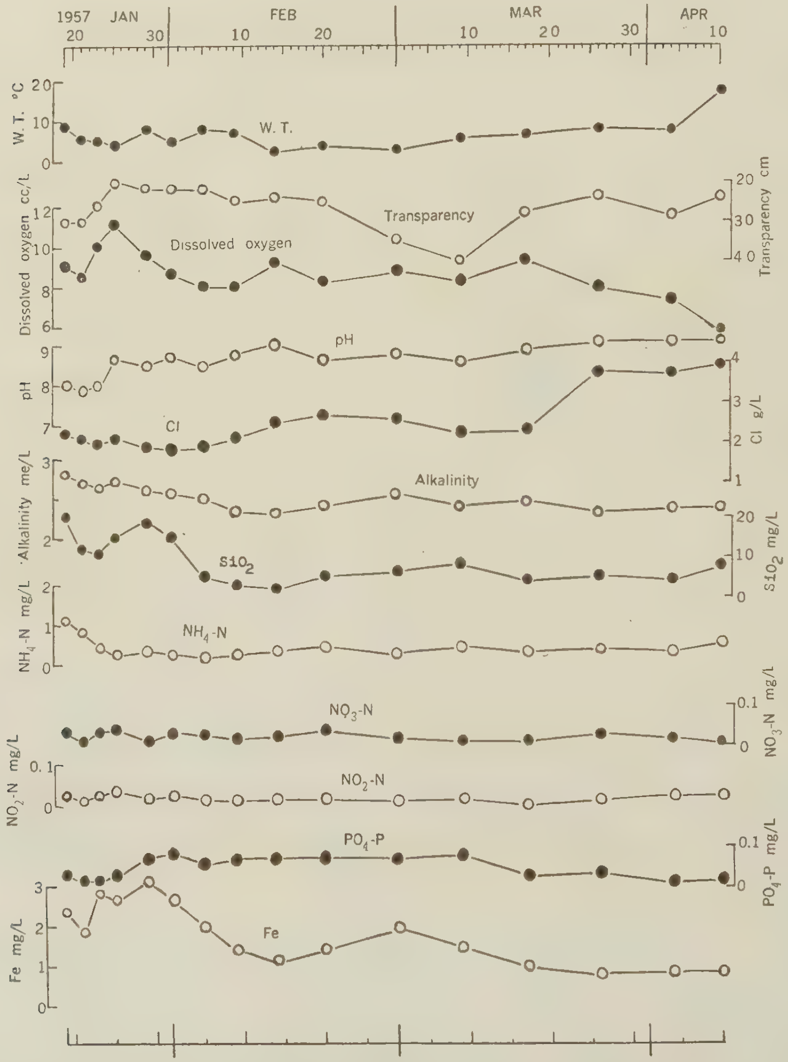

Fig. 2. The changes of physico-chemical factors after the water-renewal ("Ikegaè") of the eel-culture pond M_2, in Tsu City, Mie Prefecture. Period of the "Ikegaè": Jan. 14-18, 1957. The pond was refilled with groundwater only.

プランクトン相に対する池替の影響は，池替前の状態の観測を欠くので明かでない。

M_7 池 (Figs. 8～10)

3月26日から排水をはじめ，3月29日に排水完了。底泥を除去せず，2日間池干し。31日から地下水を注入し，4月3日に満水。

池水の塩分は池替前は Cl 7～8‰ であつたが，池替後は Cl 6‰ となり，やや低下した。池水の pH は 9.5 前後，溶存酸素は 8～10 cc/*l* で，池替前後に著しい相違はない。透明度は池替前には 30～15 cm，池替後には 30～23 cm でやや大きいが，著しい変化はない。池水の Fe は池替後地下水の注入によつて著しく増加したが，他の Alkalinity, SiO_2, NH_4-N, NO_3-N, NO_2-N, PO_4-P 等には池替前後で著しい差異はない (Fig. 8)。

植物プランクトンは，池替の前後を通じて，*Chroococcus dispersus* が優占種で，その他の植物プランクトンにも，池替前後における相並びに量には著しい差はない (Fig 9)。

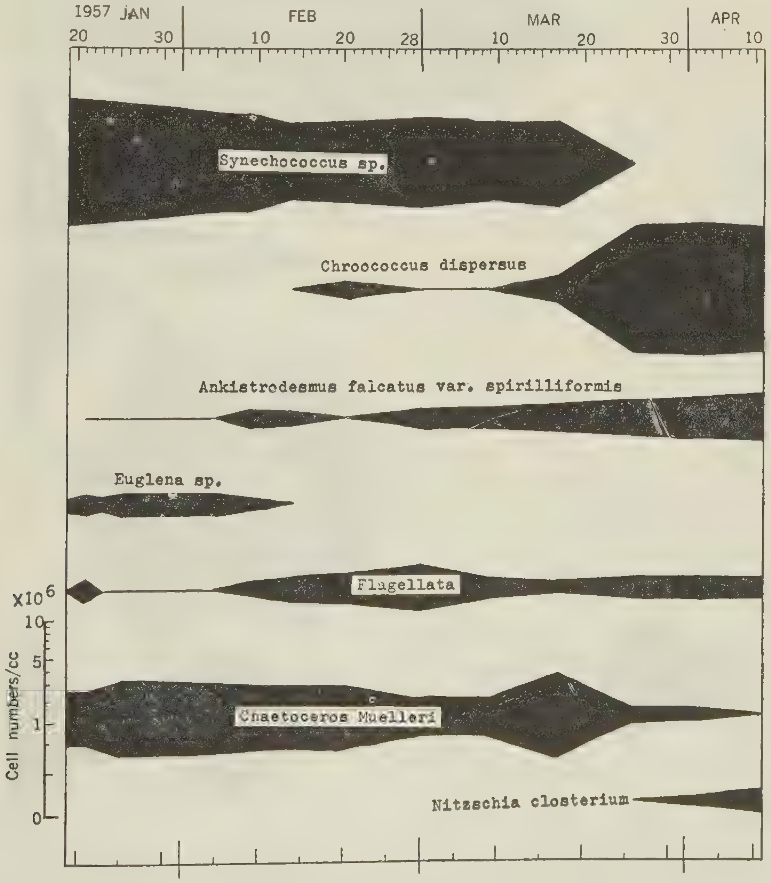

Fig. 3. The changes of phytoplankton after the "Ikegaè" in the eel-culture pond M_2, Tsu City, Mie Prefecture. Period of the "Ikegaè": Jan. 14-18, 1957. The pond was refilled with groundwater only. The figure illustrating with Lohmann's "spherical curve method".

動物プランクトンは，*Sinocalanus*, *Pseudodiaptomus* が 1 月から継続的に出現し，輪虫(種名不詳)が 2 月中旬から，*Keratella cruciformis* var. *eichwaldi* は 3 月下旬から夫々出現した。しかし，これらの種類相，量は池替前後に著しい相違はない (Fig. 10)。

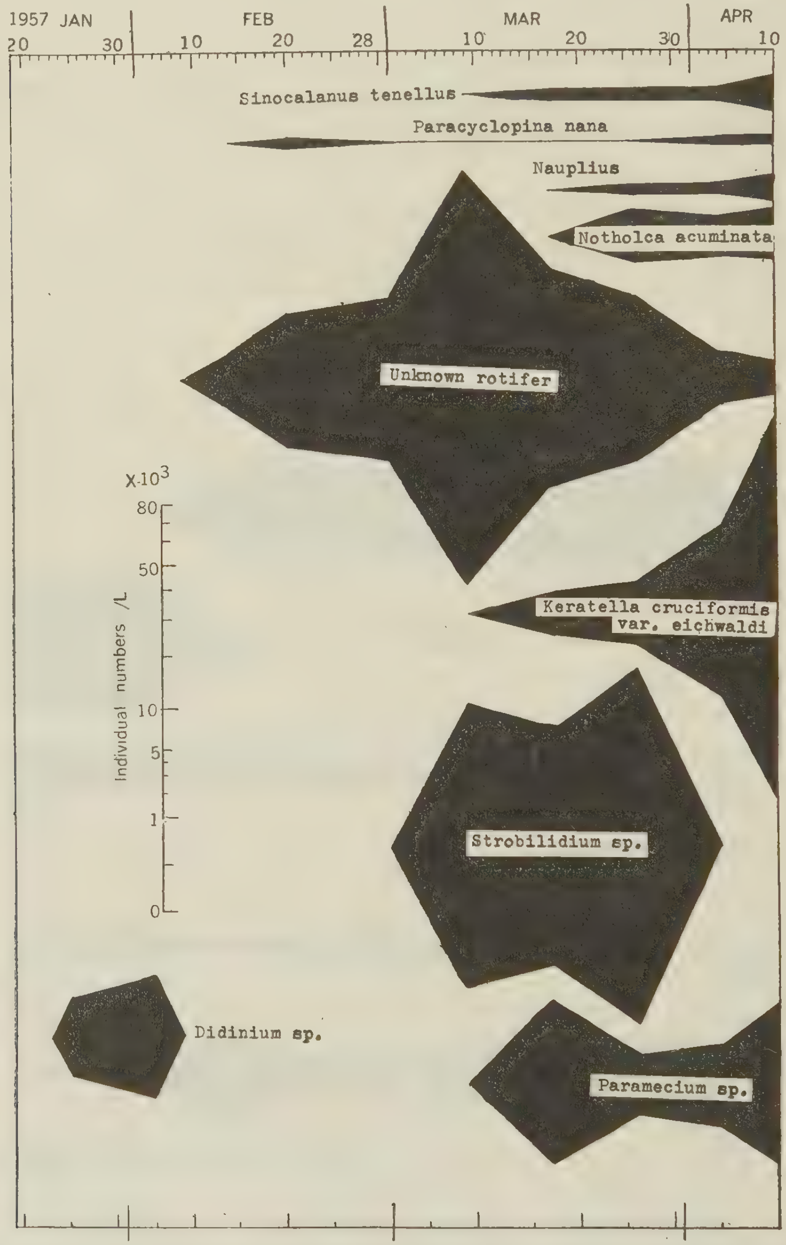

Fig. 4. The changes of zooplankton after the "Ikegaè" in the eel-culture pond M_2, Tsu City, Mie Prefecture. Period of the "Ikegaè": Jan. 14-18, 1957. The pond was refilled with groundwater only. The figure illustrating with Lohmann's "spherical curve method".

2. 底泥を除去せず，他の池水と地下水で湛水した場合

M_1 池 (Figs. 11～13)

1月25日に池替をはじめ，27日に完了。底泥はそのままで28日から2月5日にわたり池底を干す。2月6日から9日にかけて，隣接の M_2 池の新池水と地下水（M_2 池のそれと同じ）とで満水した。M_2 池水と地下水との注水量は約7:3である。

池替前後における池水の水質の変化は，Fig. 11 に明かのように，Fe は顕著に増加し，逆に透明度，溶存酸素，pH はやや低下しているが，その他の水質要素には著しい変化は見られない。透明度は2月下旬から3月上旬にかけて著しく増大するが，これは輪虫の大増殖と一致しているのは前述の M_2・M_4・M_7 池と場合と同じである。

植物プランクトンは，池替前には *Synechococcus* sp., *Dactylococcopsis* sp., *Chaetoceros Muelleri* が優占種であつた。池替後，*Dactylococcopsis* sp. は消滅したが，*Syne-*

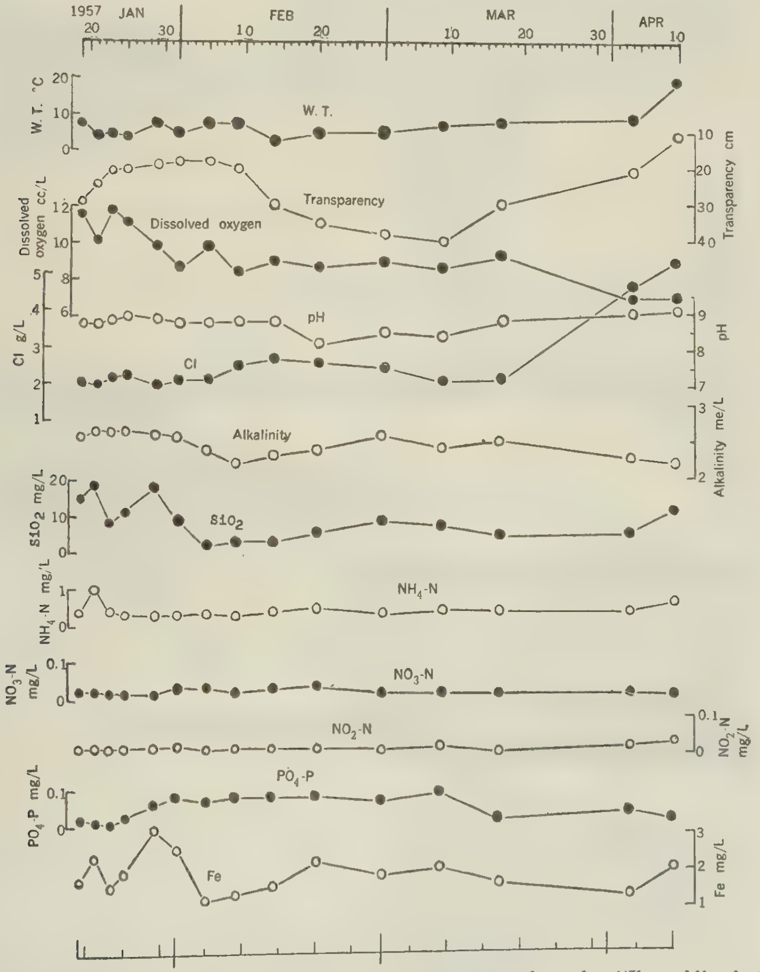

Fig. 5. The changes of physico-chemical factors after the "Ikegaè" of the eel-culture pond M_4, Tsu City, Mie Prefecture. Period of the Ikegaè": Jan. 4–13, 1957. The pond was refilled with groundwater only.

chococcus, *Chaetoceros* には著しい変化はなく，共にその後も優位を占めていた。*Chroococcus dispersus* は3月上旬から出現し大増殖をはじめた (Fig. 12)。

動物プランクトンは，池替前には *Paracyclopina nana*, *Didinium* sp., *Strobilidium* sp. の3種が見られたが，池替後にはいずれも全く見出し得なかつた。池替後2月20日

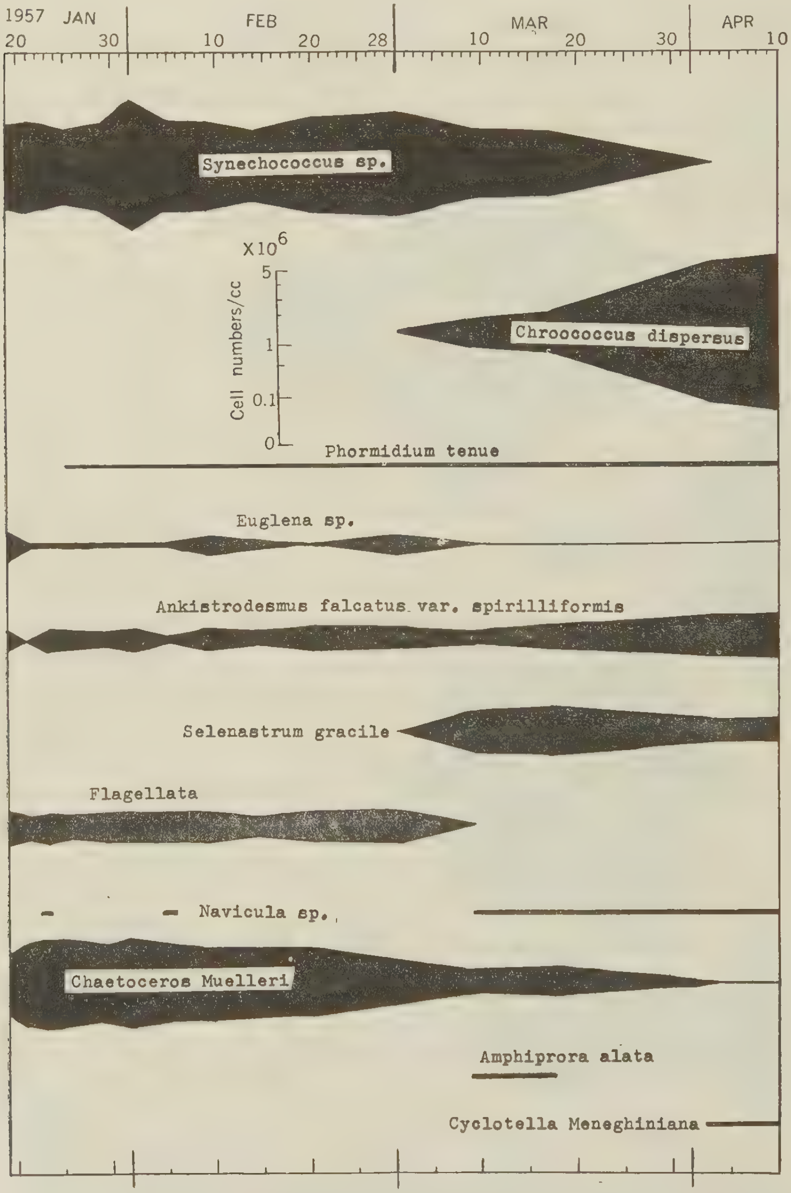

Fig. 6. The changes of phytoplankton after the "Ikegaè" in the eel-culture pond M_4, Tsu City, Mie Prefecture. Period of the Ikegaè": Jan. 4–13, 1957. The pond was refilled with groundwater only. The figure illustrating with "spherical curve method".

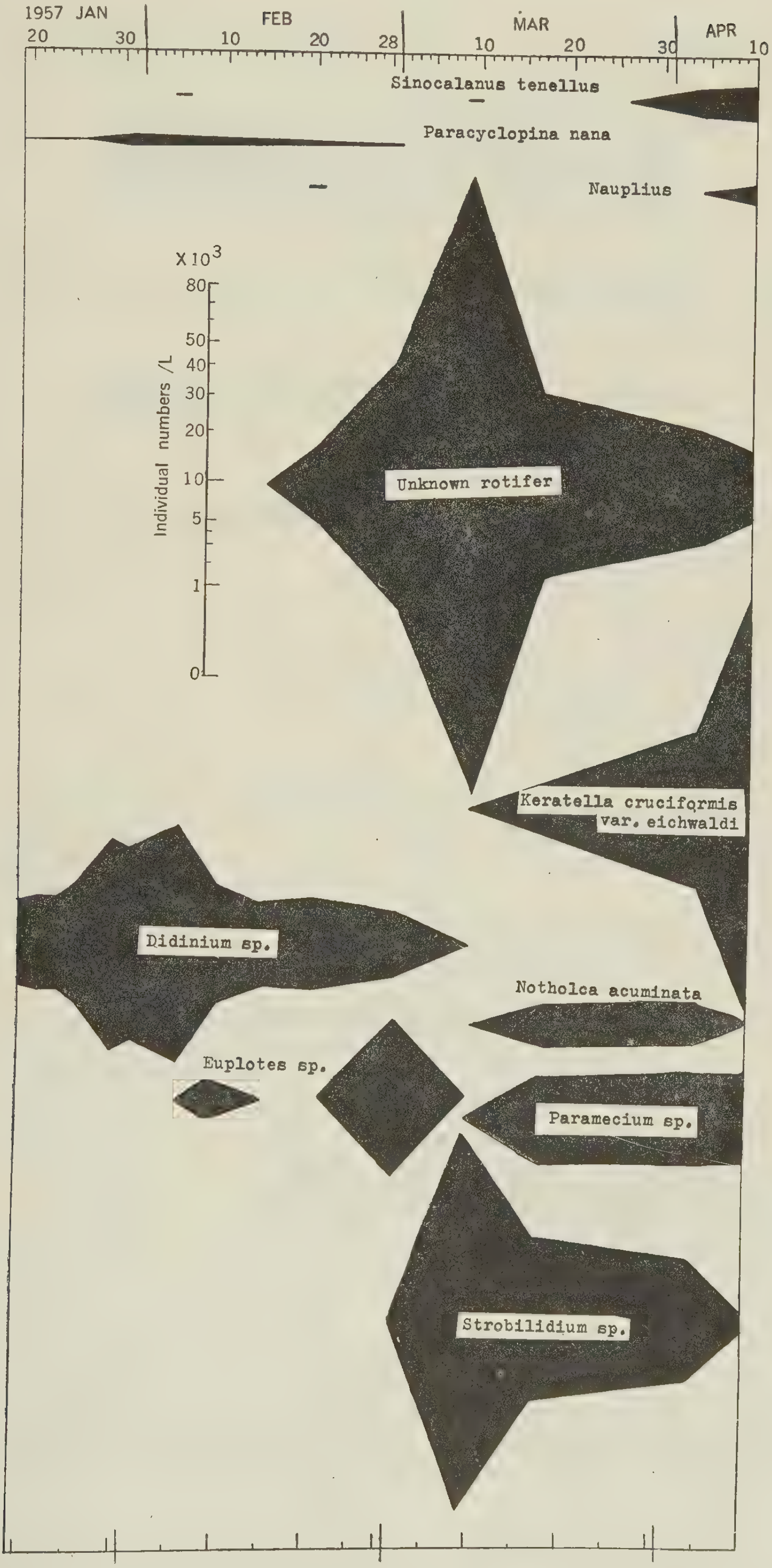

Fig. 7. The changes of zooplankton after the "Ikegaè" in the eel-culture pond M_4, Tsu City, Mie Prefecture. Period of the "Ikegaè": Jan. 4–13, 1957. The pond was refilled with groundwater only. The figure illustrating with "spherical curve method".

頃から輪虫（種名不詳）が大増殖し，3月下旬には消滅し，それに代つて，*Keratella cruciformis* var. *eichwaldi*, *Sinocalanus tenellus* 等が増殖した。(Fig. 13)。

3.　底泥を除去し，地下水と他池水で湛水した場合

K_2　池　(Figs. 14～16)

2月10日から排水をはじめ，13日に池替を完了。2月15日から24日にわたり中央部の浮泥を排出。25日から隣接の K_1 池水を注入，残りを地下水で3月5日に満水した。池水と地下水の注入量は約1:1である。

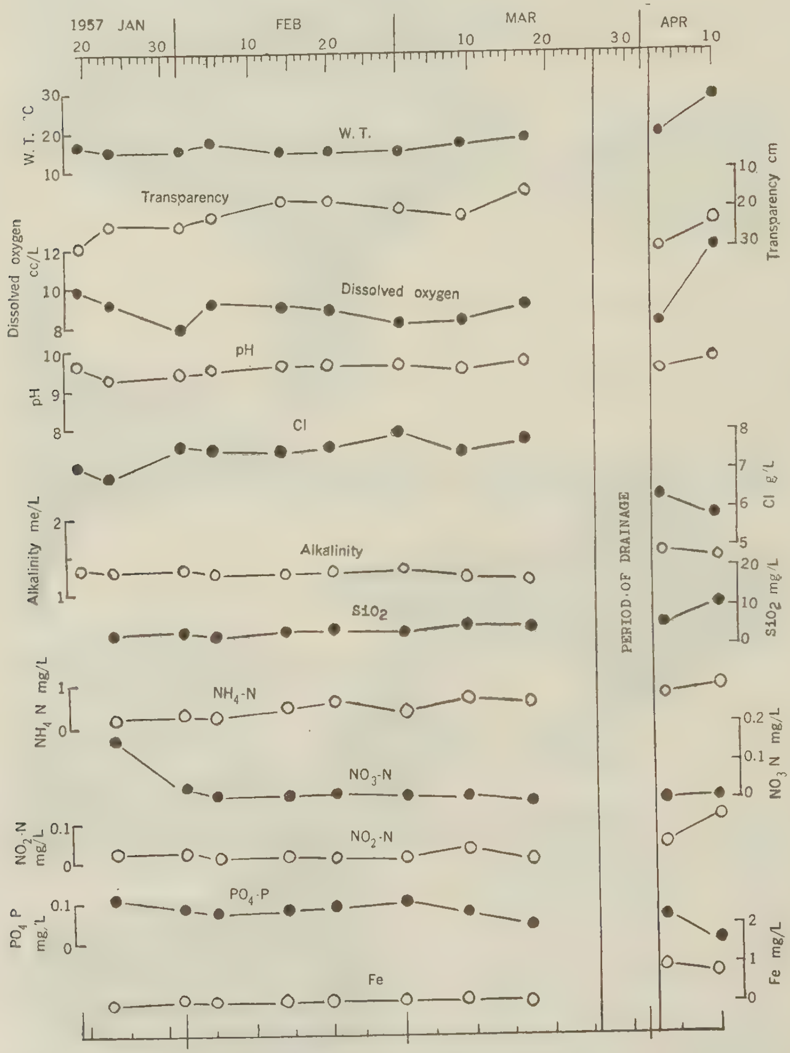

Fig. 8. The changes of physico-chemical factors in the eel-culture pond M_7, Tsu City, Mie Prefecture. Period of the "Ikegaè": Mar. 26–Apr. 2, 1957. The pond was refilled with groundwater only.

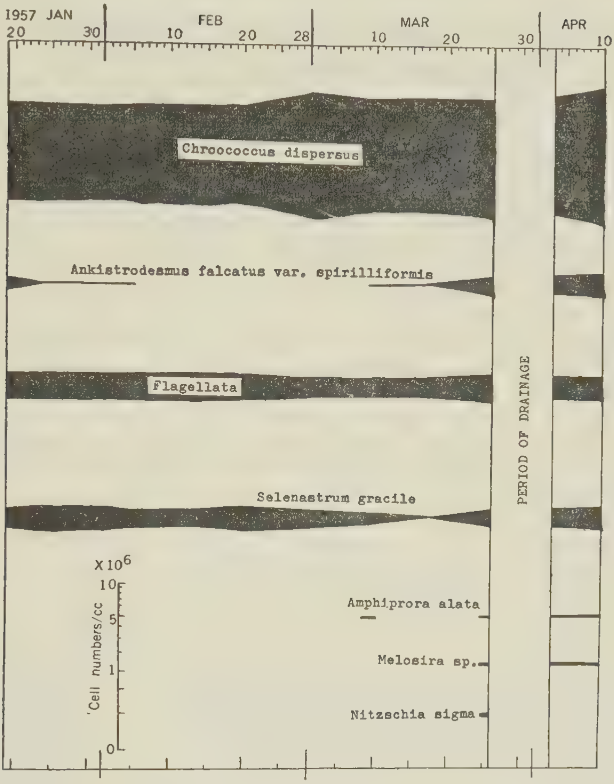

Fig. 9. The changes of phytoplankton in the eel-culture pond M_7, Tsu City, Mie Prefecture. Period of the "Ikegaè": Mar. 26–Apr. 2, 1957. The pond was refilled with groundwater only. The figure illustrating with "spherical curve method".

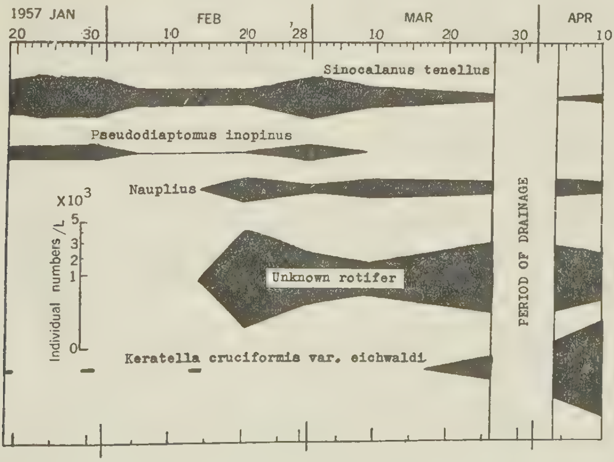

Fig. 10. The changes of zooplankton in the eel-culture pond M_7, Tsu City, Mie Prefecture. Period of the "Ikegaè": Mar. 26–Apr. 2, 1957. The pond was refilled with groundwater only. The figure illustrating with "spherical curve method".

K_2 池の源水用地下水の水質は Table 3 に示した。溶存酸素が極度に少い。

池水の塩分は 10 月下旬 (Cl 1.8‰) から池替期にかけて次第に増加し，池替中の 2 月 14 日には Cl 6‰ を示した。しかし池替後，池水の塩分は急激に 3.7〜4‰ に低下し，その後 4 月中旬にかけて徐々に増加し，それ以降は次第に減少した。その他の水質要素には池替前後に著しい相違は見られない (Fig. 14)。

植物プランクトンの種類相は極めて豊富で，優位を占める種類は，*Chroococcus dispersus*, *Selenastrum gracile*, *Ankistrodesmus falcatus* var. *spirilliformis*, *Euglena*

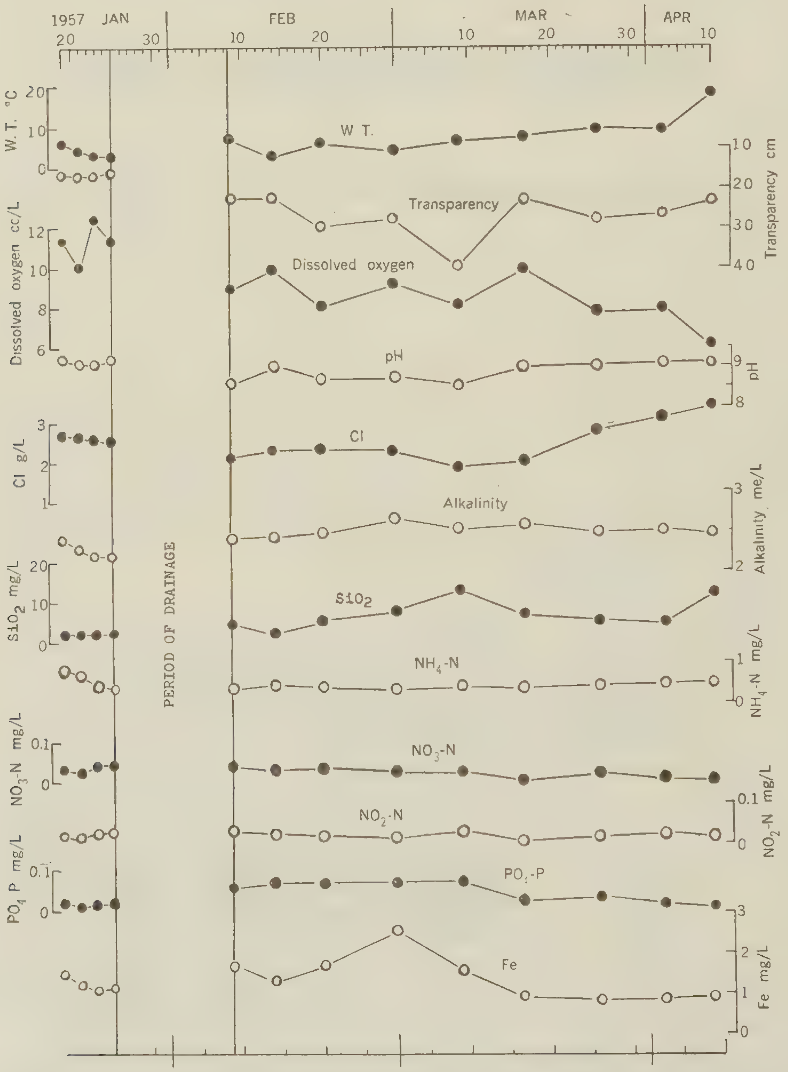

Fig. 11. The effects of the water-renewal ("Ikegaè") upon the physico-chemical factors of the eel-culture pond M_1, Tsu City, Mie Prefecture. Period of the "Ikegaè": Jan. 25–Feb. 9, 1957. The pond was refilled with groundwater and the old pond water of M_2.

Table 3. The water quality of the groundwater used for the water source of the eel-culture pond K_2.

Elements	Date 1957				
	Mar. 5	Mar. 7	Mar. 9	Mar. 12	Apr. 25
Time	10.15	10.05	10.10	10.30	10.25
A. T. °C	6.9	4.9	7.6	2.8	15.5
W. T. °C	7.8	16.8	16.3	8.0	17.1
Water colour	clear	〃	〃	〃	〃
pH	<6.8	<6.8	<6.8	<6.8	—
Dissolved oxygen ccl/*l*	0.06	0.09	0.86	0.06	0.11
%	0.7	1.3	12.4	1.2	1.6
Transparency	—	—	—	—	—
Alkalinity me/*l*	0.68	0.70	0.64	0.68	1.72
Cl g/*l*	2.14	2.03	1.92	1.89	0.44

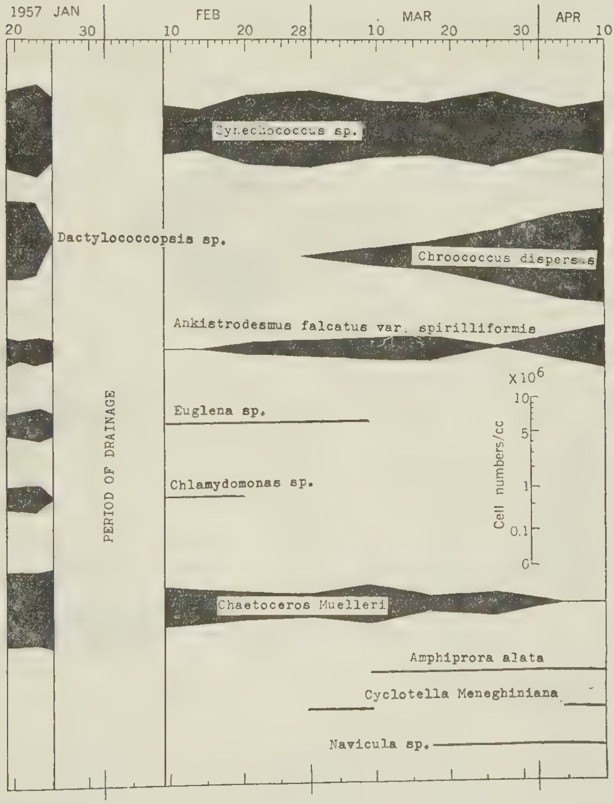

Fig. 12. The effects of the "Ikegaè" upon the phytoplankton in the eel-culture pond M_1. Period of the "Ikegaè": Jan. 25–Feb. 9, 1957. The pond was refilled with groundwater and old pond water of M_2. The figure illustrating with "spherical curve method".

sp., *Chlamydomonas* sp., *Oocystis solitaria*, *Cyclotella glomerata*, *Chaetoceros Muelleri* 等である。これらは池替によつて殆んど影響を受けていない (Fig. 15)。

池替前の動物プランクトン相は Fig. 16 明かのように，極めて単調で，繊毛虫類の *Didinium* sp. のみより成る。池替後 *Didinium* の密度は急減し，痕跡的となつた。他のプランクトン動物に対する池替の影響は明かでない。

池替後，*Sinocalanus tenellus* とその nauplius，種名不詳の輪虫が最初に出現し，特にこの輪虫は4月3日に最大密度に達し，その後10日には消滅し，*Keratella cruciformis* var. *eichwaldi* と交替し，*Keratella* は4月下旬に最大密度に達した。*Keratella* の減少とは逆に，*Brachionus quadridentatus* が大増殖し，この輪虫は 6 月上旬には消滅し，*Brachionus plicatilis* と交替した。その他 *Pseudodiaptomus inopinus*, *Paracyclopina nana*, *Brachionus urceolaris* が4月下旬から出現している。前述の輪虫(種名不詳), *K. cruciformis* var. *eichwaldi*, *Br. quadridentatus*, *Br. plicatilis* の大増殖時には，池水の透明度，溶存酸素，pH 等は低下している。特に *Br. quadridentatus*, *Br. plicatilis* の大増殖時における変化が大きく，養殖魚は鼻上げをした。また Fig. 15 に明かのように，植物プランクトンの優占種，*Chroococcus dispersus*, *Gomphosphaeria lacustris* はこの水変りで急激に減少し消滅した。

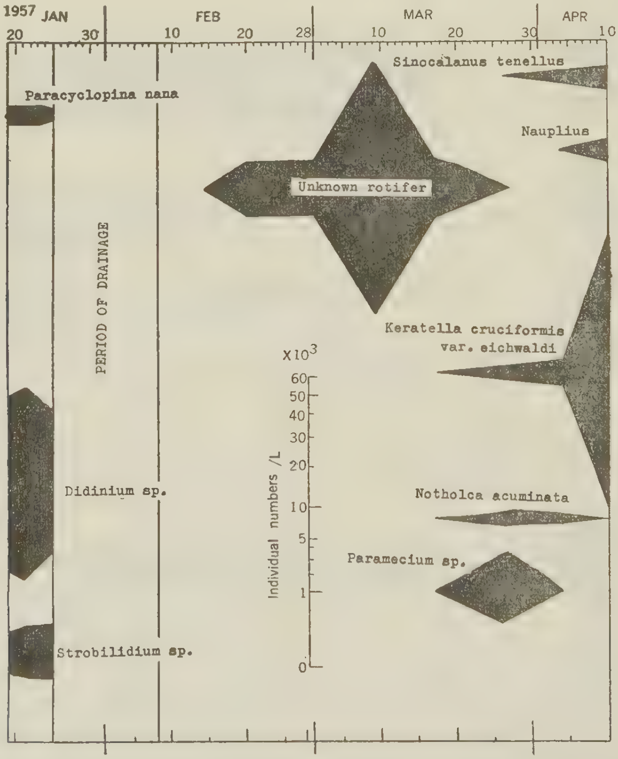

Fig. 13. The effects of the "Ikegaè" upon the zooplankton in the eel-culture pond M_1. Period of the "Ikegaè": Jan. 25–Feb. 9, 1957. The pond was refilled with groundwater and the old pond water of M_2. The figure illustrating with "spherical curve method".

O_1 池 (Figs. 17～19)

2月10日から池替をはじめ，13日に排水完了。2月15日から中央部の浮泥を排出し，その後約1ヶ月間池底を干した。3月12日から O_2 池の旧池水（緑色）を注入し，地下水で3月14日に満水した。緑色池水と地下水の注入量の割合は約1:1である。

池替後，池水の塩分は Cl 4.9‰ から Cl 3.7‰ に低下し，逆に池水の溶存酸素，pH は上昇した。その他の水質には池替前後に著しい変化はない。また池替後約1ヶ月位は透明度，pH，溶存酸素に著しい変動はないが，4月下旬から変動が大きくなつている。これは後述のように輪虫の大増殖と一致している (Fig. 17)。

池替の前後における植物プランクトン相は K_2 池のそれに類似し，極めて豊富で，*Chroococcus dispersus*, *Synechococcus* sp., *Selenastrum gracile* 等が優占種をなし，かつ池替の前後で種類並びに量的の著しい変化はない (Fig. 18)。

池替前の動物プランクトンは，汽水性橈脚類の *Pseudodiaptomus inopinus*, *Paracyclopina nana* の2種よりなり，極めて単調であるが，この2種は池替後，殆んど消滅した。

池替後最初に出現した動物プランクトンは，*Sinocalanus tenellus*, その nauplius, 種名不詳の輪虫である。この点は K_2 池のそれに一致するが，輪虫（種名不詳），*Keratella cruciformis* var. *eichwaldi*, *Br. quadridentatus* には大増殖は見られず，*Br. plicatilis*

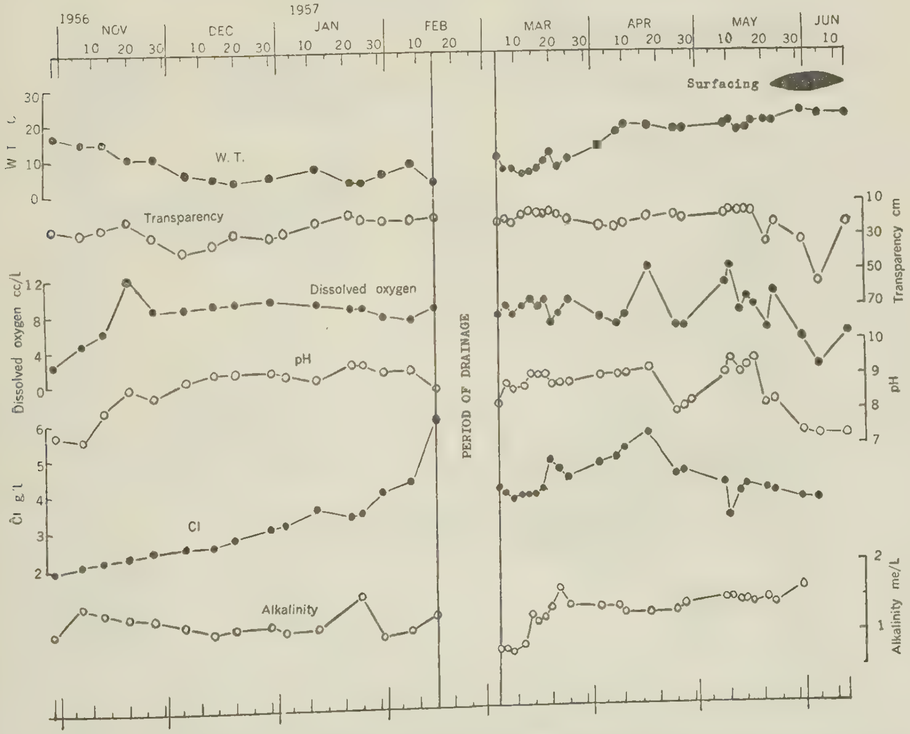

Fig. 14. The weekly changes of physico-chemical factors in the eel-culture pond K_2, Tsu City, Mie Prefecture. Period of the "Ikegaè": Feb. 13–Mar. 5, 1957. The pond was refilled with groundwater and the old pond water of K_1.

並びに *Br. urceolaris* の2種の輪虫と，枝角類の *Moina dubia* に大増殖の見られたことは K_2 池のそれと異る。これらの3種のプランクトン動物の大増殖時には，夫々ウナギの餌付皆無，鼻上げ等の異常現象が見られ，植物プランクトンは急減し，透明度，pH，溶存酸素も低下し，水変りが見られている (Figs. 17~19)。

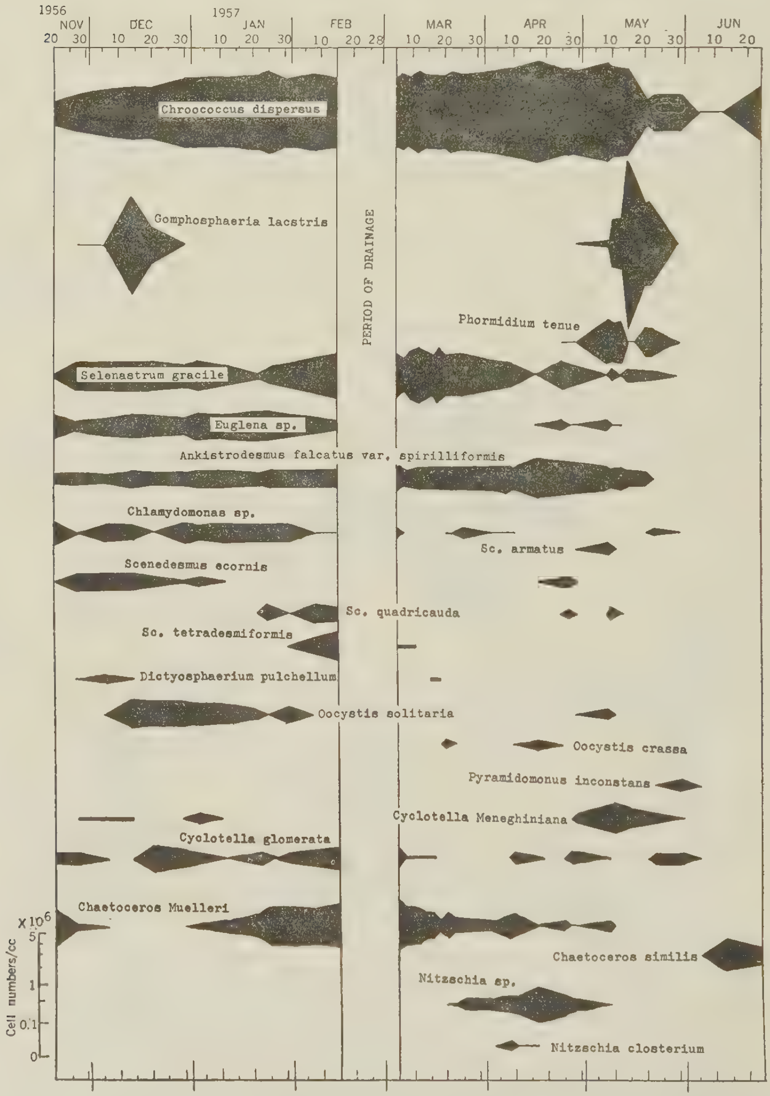

Fig. 15. The weekly changes of the phytoplankton in the eel-culture pond K_2. Period of the "Ikegaè: Feb. 13-Mar. 5, 1957. The pond was refilled with groundwater and the old pond water of K_1. The figure illustrating with "spherical curve method".

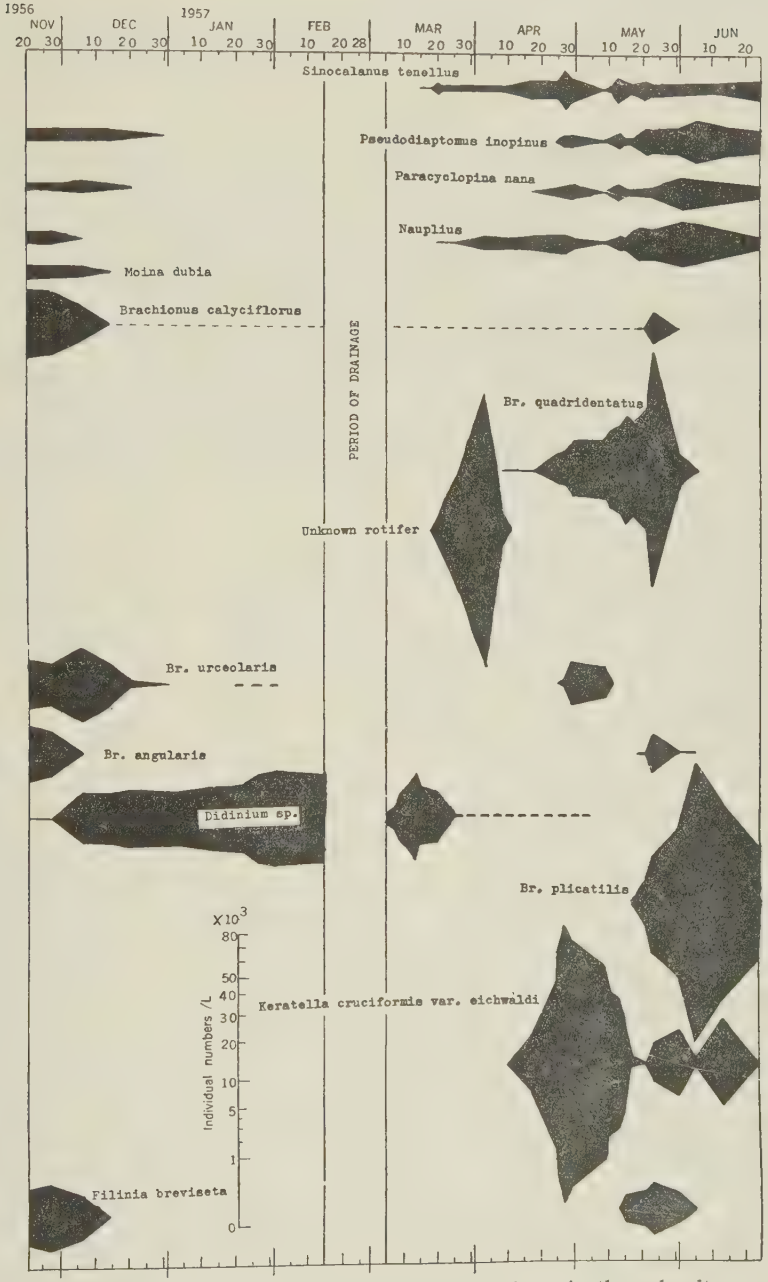

Fig. 16. The weekly changes of the zooplankton in the eel-culture pond K_2. Period of the "Ikegaè": Feb. 13–Mar. 5, 1957. The pond was refilled with groundwater and the old water of K_1. The figure illustrating with "spherical curve method".

IV. 総括並びに考察

1. 津市北部の養鰻池群における冬期のプランクトン相

津市北部の前述の $M_1, M_2, M_4, M_7, K_2, O_1$ 池の 6 面の養鰻池 (Cl 2～6‰) における，1 月～4 月の冷水期のプランクトン相の特徴は次のように総括される。

1) 植物プランクトン

植物プランクトンを構成しているも種数は，池によつて異るが，6 種乃至 15 種で，M_7 池が最も単調で，K_2, O_1 両池が最も豊富である。優占種は，藍藻類の *Chroococcus dispersus*, *Synechococcus* sp. の 2 種で，M_7, K_2, O_1 池では前者が，M_1, M_2, M_4 池では後者が 1 月から 4 月にわたり持続的に卓越する。次に卓越した種類は，緑藻の *Selenastrum*

Table 4. Winter phytoplankton in six eel-culture ponds in the northern part of Tsu City, Mie Prefecture, Middle Japan, 1957.

Phytoplankters	Eel-culture ponds					
	M_1	M_2	M_4	M_7	K_2	O_1
Cyanophyceae						
Synechococcus sp.	cc	cc	cc			cc
Chrococcus dispersus	cc	cc	cc	cc	cc	cc
Dactyloccopsis sp.	c					
Phormidium tenue			r		+	
Gomphosphaeria lacustris					c	
Anabaenopsis Tanganyikae						r
Chlorophyceae						
Ankistrodesmus falcatus	+	+	+	+	+	+
Euglena sp.	+	+	+		+	r
Chlamydomonas sp.	+	+	c	c	+	
Selenastrum gracile			c	c	c	c
Scenedesmus ecornis					+	+
Sc. quadricauda					+	
Sc. tetradesmiformis					r	r
Sc. carabus						r
Crucigenia tetrapedia						+
Oocystis solitaria					+	
Dictyosphaerium pulchellum					r	
Diatoms						
Chaetoceros Muelleri	c	c	c		c	c
Amphiprora alata	rr		rr			
Cyclotella Meneghiniana	rr		rr		+	
C. glomerata					+	+
Nitzschia closterium		+				+
N. sp.				rr		+
Navicula sp.	rr		rr			
Melosira sp.				rr		
Number of species	10	7	11	6	15	14

gracile, *Ankistrodesmus falcatus* var. *spirilliformis*, 硅藻の *Chaetoceros Muelleri* 等である。これらの優占種の細胞あるいは群体は極めて小さく，3～15 μ で，いわゆる "micron algae" に属している。これらの micron algae は輪虫の餌料として適当であり，4月下旬から6月上旬における輪虫の発生，大増殖と，それによる水変りと重要な関係をもつているといえよう。[1),2),3),4),5),6),7),8),9),10)]

2) 動物プランクトン

1月から4月にわたる冷水期の動物プランクトン相は，植物プランクトン相に比べて，極めて貧弱で，橈脚類と纖毛虫類によつて代表され，主な種類は，*Sinocalanus tenellus*, *Pseudodiaptomus inopinus*, *Paracyclopina nana*, *Didinium* sp., *Strobilidium* sp., *Paramecium* sp. 等であるが，これらの個体数密度は極めて小さい。

水変りの最も有力な原因となる輪虫類の出現と季節遷移は次のように総括できる。

最初に出現する輪虫は，種名不詳の輪虫であり，6面の養鰻池に共通に見られた。2月5日～20日 (W. T. 4.4～4.9°C) から出現し，急激に増殖し，3月17日～4月3日 (W.T. 8.8～9.2°C) には全く消滅する。最大密度は314個体/cc に達する場合もある。40～50個体/cc 以上の密度に達する場合には，透明度，pH，溶存酸素は低下し，水変り類似の現象が見られるが，養殖魚の異常現象は認められなかつた。低温と給餌前であるためであろう。

次に出現する輪虫は，*Keratella cruciformis* var. *eichwaldi* である。出現期は池によつて多少異なり，M_1, M_2, M_4 池では3月16日～26日 (W. T. 9.3～9.7°C), M_7, K_2, O_1

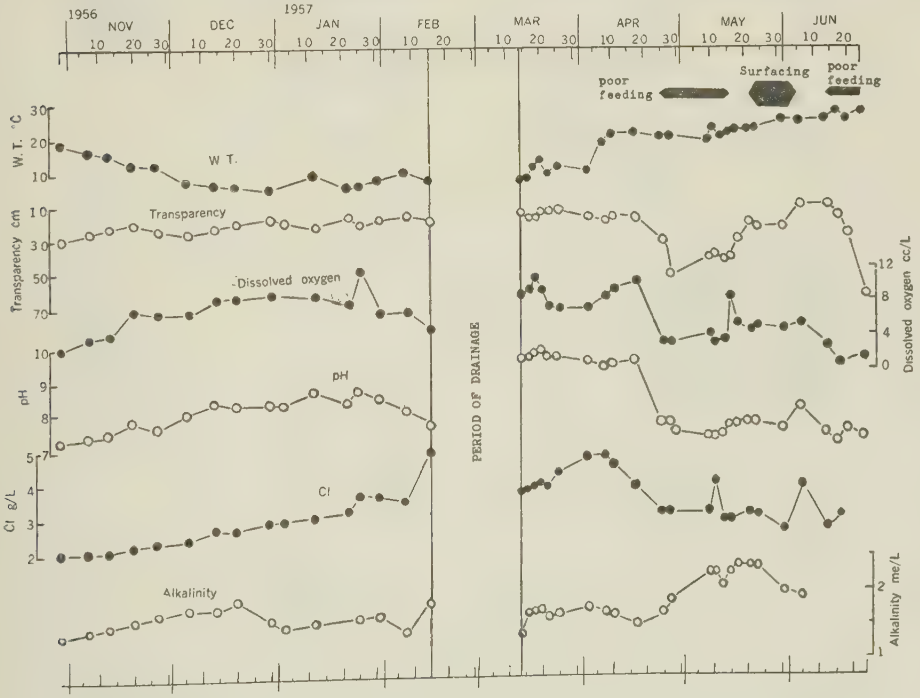

Fig. 17. The weekly changes of physico-chemical factors in the eel-culture pond O_1, Tsu City, Mie Prefecture. Period of the "Ikegaè": Feb. 13–Mar. 14, 1957. The pond was refilled with groundwater and the pond water of O_2.

池では 4 月 10 日～ 25 日 (W. T. 18～19°C) から出現しはじめ，5 月下旬～6 月上旬には全く消滅する。最大密度は 96 個体/cc に達した。K_2 池では 4 月 27 日に最大密度 69 個体を示し，水変り現象が見られたが，養殖魚に異常は認められなかつた。また M_1, M_4 池では，いずれも 4 月 10 日に夫々 46 個体/cc, 96 個体/cc の最大密度が見られたが，水変り現象は見られなかつた。しかし，5 月以降の給餌後における本種の大増殖による水変りと養殖魚の被害については，すでに第 12 報[2]に報告した。

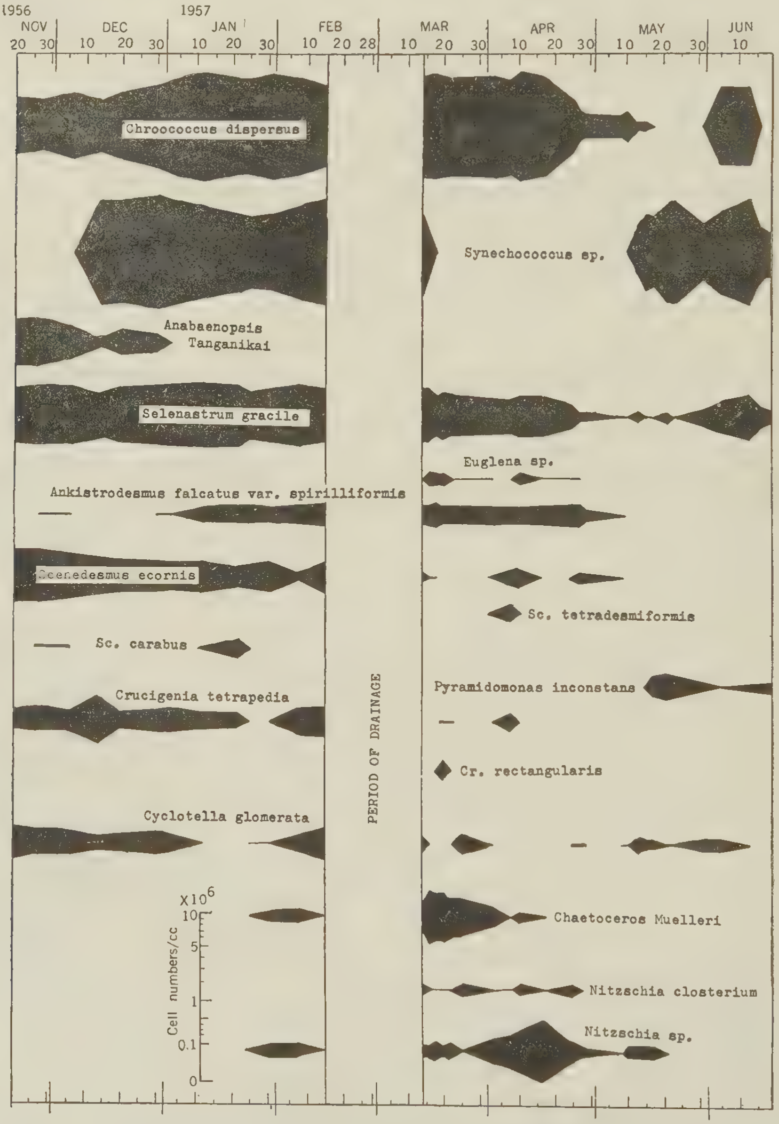

Fig. 18. The weekly succession of the phytoplankton in the eel-culture pond O_1. Period of the "Ikegaè": Feb. 13–Mar. 14, 1957. The pond was refilled with groundwater and the old pond water of O_2. The figure illustrating with "spherical curve method".

次いで大増殖をする輪虫は, *Brachionus quadridentatus*, *Br. urceolaris*, *Br. calyciflorus* 等である。この3種は4月下旬～5月上旬に期を同じくして出現する。そのときの水温は約18～21°C である。K_2 池では *Br. quadridentatus* が5月23日に44個体に達し，水変りの原因となり，O_1 池では *Br. urceolaris* が4月27日に13個体/cc を示し，*Br. plicatilis* の大増殖と共に餌付皆無の水変りの原因の1部をなしていると考える。

最後に，温水期に最も卓越し，汽水養鰻池における水変りの最有力な原因となる *Br. plicatilis* が出現する。K_2 池では5月23日 (W. T. 20°C), O_1 池では4月26日 (W. T.

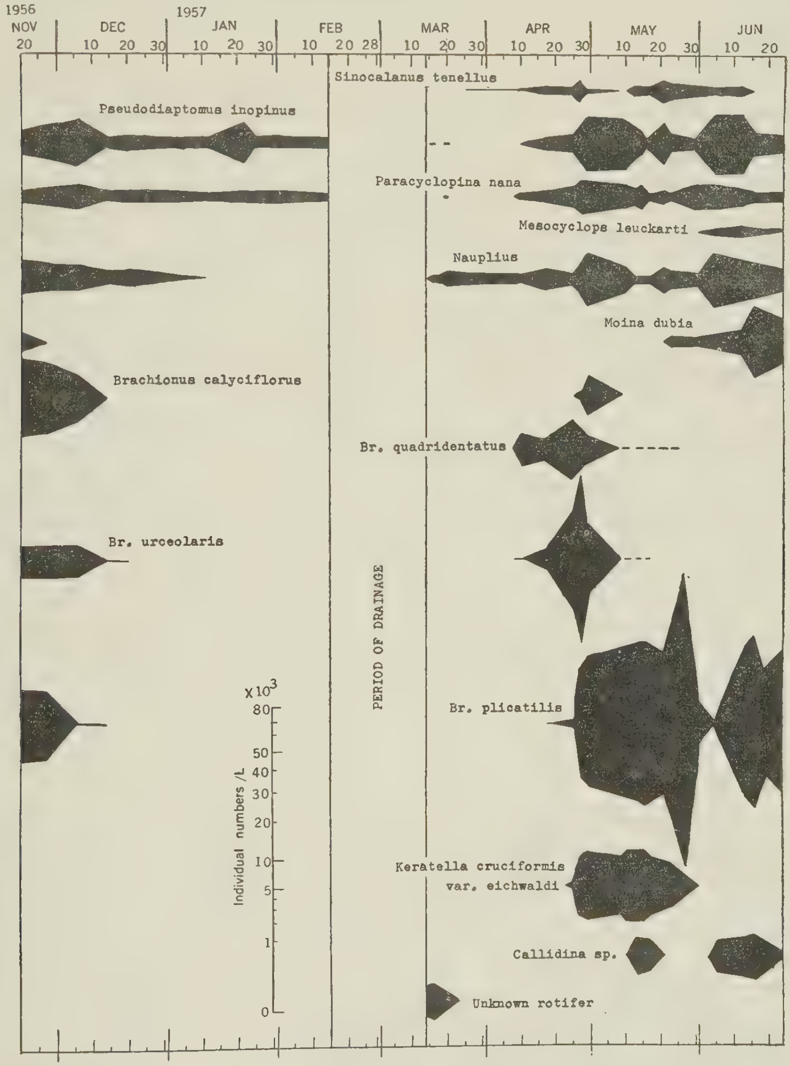

Fig. 19. The weekly succession of the zooplankton in the eel-culture pond O_1. Period of the "Ikegaè": Feb. 13–Mar. 14, 1957. The pond is refilled with groundwater and the old pond water of O_2. The figure illustrating with "spherical curve method".

17.9°C) から出現しはじめた。K_2 池では 6 月 5 日に 69 個体/cc, O_1 池では 5 月 25 日に 65 個体/cc に達し，共にウナギの鼻上以上の程度の水変りの原因となつている。

以上の 1 月から 6 月にわたる津北部の養鰻池群における輪虫の季節遷移は次のように要約できる。

Unknown rotifer (2〜3 月) → *Keratella cruciformis* var. *eichwaldi* (4〜5 月) → *Brachionus quadridentatus* (or *Br. urceolaris*; 5 月) →*Br. plicatilis* (5, 6月〜12 月)

そして，*Br. plicatilis*; *Br. quadridentatus*; *Br. urceolaris*, *Br. calyciflorus*, *Br. augularis*, *Filinia breviseta* 等の輪虫類は 12 月中旬には殆んど消滅する[1]。

2. 養鰻池のプランクトン相に対する冬期池替の影響並びに池替後におけるプランクトン相の形成

津市北部の養鰻池群における池替の時期は，前述したように，1 月上旬から 4 月上旬の長期にわたり，池によつて区々である。また池干し期間も異り，底泥を除去したものもあり，全く除去しないものもあり，かつ排水後の源水は，地下水のみ，あるいは地下水と旧池水との混合もあり，その混合割合も種々である。それにも拘わらず，池替後の植物プランクトンは，池替前に卓越していた種類が 1 週間以内に急速に増殖し，また水質条件も池替前に回帰している。また動物プランクトンも，池替の諸条件の多様性にも拘わらず，どの池においても同じ種類が殆んど時期を同じくして出現し，遷移している。また池替の前後において種類相の著しい変化も見られない。従つて養鰻池における冬期池替はプランクトン相に対し著しい影響を与えるものとはいえない。その地方の固有の遷移系列に沿つたプランクトン相の動きは池替によつては乱されないと考えるのが妥当のようである。

このような養鰻池のプランクトン相の特異性，恒常性はどのような原因に依存するのであろうか。これは養鰻池のプランクトンは藻類のみでなく，動物も環境条件(水質・温度，乾燥等) の変化に対する耐忍性が極めて大きい[8),10),12)]。悪条件下では胞子・cyst・耐久卵等の形で休眠する[11)]。排水並びに底泥の除去によつても上述のプランクトンの発生源を取り除くことは不可能である，等がその原因であると考えられる。

最後に本研究の費用の 1 部は，昭和 32 年度文部省科学研究費に仰いだ。ここに謝意を表します。なお本研究の大要は日本水産学会大阪大会 (昭 34, 10 月) において口頭発表したものである。

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養鰻池の水変りに関する研究—XXI.

養殖池と天然池の比較

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Studies on the "Mizukawari" in Eel-Culture Ponds—XXI.

Comparison between Eel-Culture Pond and Natural Fish Ponds

(*With 14 Text-figures and 3 Tables*)

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(Limnological Laboratory, Faculty of Fisheries,
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Résumé

The "Mizukawari," in the eel-culture ponds in the extensive culture period being trifle, has become serious in the present intensive culture period. This study was made to clarify that cause and mechanism. The researches were made in the water quality, phytoplankton, zooplankton and "Mizukawari" in a mixohaline eel-culture pond (N_1, area 16.5 a, depth 1 m, without large aquatic plants) and in two natural fish ponds (N_2 and N_3, areas 263 a and 68.8 a, depth 1 m, covered with *Potamogeton pectinatus*) in Kawage-chô, Mie Prefecture, Middle Japan, in the period, from March to Sept., 1959.

The results of the survey were compared between the eel-culture pond and the natural fish ponds.

1) Water quality

The surface water temperature goes with the air temperature, no considerable difference was observed in the three ponds. The water temperature stood the maximum 31-32° C on the early days of August. The salinity of the pond water was the lowest of Cl 1.8-3.2‰ in Pond N_3, and between Pond N_2 (Cl 3.6-2.2‰) and Pond N_1 (Cl 3.6-2.2‰) no difference was found in the salinity. In other words, the three ponds belong to β-Mesohaline or α-Oligohaline mixohaline water[6]. The alkalinity of the pond water is, with no difference between the ponds, 1~2 me/1. The transparency differs with the standing crops of phytoplankton, and the minimum is 18 cm in Pond N_1 and 40 cm in Pond N_2 and almost transparent in Pond N_3. The pH is the highest and stable in Pond N_3, followed by Pond N_2 and is the lowest and quite unstable in Pond N_1. The dissolved oxygen is the most in Pond N_3, but in Pond N_1 it is the least stable, and that of Pond N_2 comes between them. The contents of nutrients, NO_3-N, NO_2-N, NH_4-N, PO_4-P and Fe, are showed constantly the most in Pond N_1, followed by Pond N_2, and the least in Pond N_3.

2) Phytoplankton

The number of species is the largest in Pond N_1, especially of blue-green algae and green algae; that of Pond N_2 comes next and the smallest in Pond N_3. But in all the three ponds, the micron-algae, *Synechococcus* sp., *Chroococcus dispersus*, *Selenastrum gracile*, *Cyclotella glomerata* and *Nitzschia closterium*, are the dominant

species, and the seasonal successions are all the same. The standing crops of phytoplankton in the three ponds showed no difference in diatoms, but the standing crops of blue-green algae and green algae show the most in Pond N_1, 2-4 times and 10 times as many as the other two ponds, respectively. Consequently, it can be said that the production of micron-algae is far more in the eel-culture pond than in the natural fish ponds.

3) Zooplankton

No difference in the plankton fauna and in the seasonal seccession were found in the three ponds. But the difference in the maximum standing crops is conspicuous; in Pond N_1, Crustacea is 20–30 times, Rotifera 8–45 times, and Ciliata 8–19 times as much as in Ponds N_2 and N_3.
The productivity of the dormant eggs in *Br. plicatilis* is the greatest in the eel-culture pond (N_1) but weak in the natural fish ponds (N_2 and N_3).

4) "Mizukawari" phenomenon

In the eel-culture pond (N_1), "Mizukawari" occurred twice, in the middle of July and the beginning of August, the cultured eels died and the surfacing was observed in each time. These two "Mizukawari" were accompanied by the exclusive increases of mixohaline rotifer, *Brachionus plicatilis*. On the other hand, no "Mizukawari" was observed in the natural fish ponds (N_1 and N_3).

5) Conclusion

In the eel-culture pond, comparing with the natural fish ponds, the contents of nutrients, N, P and Fe, are always large, the standing crops of micron-algae and of zooplankton are also large, and especially, the rotifer exclusively increased and serious "Mizukawari" occurred: the cultured eels died and the surfacing was also observed. In the natural fish ponds, however, no "Mizukawari" was observed. These differences in the different two typed ponds are considered to be deepened by the fact that the eel-culture pond lacks in large aquatic plants.[13)]

These results may lead us to conclude that the cause and mechanism which make the "Mizukawari" much more serious in the intensive culture period are explained by the following causal chain system.

Intensive fish culture (the increase in fish density and feeding)
↓
The increase of nutrients in the pond water
↓
The increase in standing crop of phytoplankton (esp. micron-algae)
↓
The increase in standing crop of zooplankton
(especially the increase in the growth and the speed of the growth of rotifers)
↓
The increase in the degree of "Mizukawari"
↓
The increase of the damage in the cultured eels

I. 緒　　論

養鰻池における水変りは，粗放的養魚期には軽微であつたが，大量のウナギの斃死を伴つたひどい水変りは，放養量並びに給餌量が大きくなつた集約的養魚期に至つて見られるようになつたという。[1)] 水変りは植物プランクトンの少い，透明度の大きい養鰻池には殆んど見られないが，このような池では養魚成績は不良である。しかし施肥によつて植物プランクトンが増殖し，"水ができる"と，輪虫の増殖量と増殖速度は著しく増大し，ひどい水変りがおこる実例が報告されている[2)]。輪虫類による水変りは，餌料としての植物プランクトン量が大きい程，輪虫の増殖速度と増殖量は大きくなり，水変りの速度と変化量

も大きくなつて，ひどい水変りになる可能性は実験的にも明かにされている[3)4)5)]。

養鰻池における水変りが，集約的養魚になつてから大規模になつた原因並びにその機構は何であろうか。この問題は水変りの程度を決定する要因の解明にも重要な関係をもつている。この原因と機構は，伊藤の水変り理論[4)]を適用すると，集約養魚（放養量・給餌量を増加)→栄養塩類の増加→植物プランクトンの増加→動物プランクトン(特に輪虫類・繊毛虫類・枝角類）の増殖量の増大→水変りの程度の増大→養殖魚の被害の増大によつて説明できよう。この考えが妥当であるか，どうかは，投餌養鰻池（養殖池）と無投餌養魚池(天然池)の，水質，溶存酸素の日週変化，植物プランクトン量，動物プランクトン量，水変り等を長期にわたつて観測し，その結果を比較することによつて明かにできるであろう。本研究はこのような意図の下に行われたものである。

本研究の企画は伊藤が立案し，野外観測の大部分は丹羽が，植物プランクトンは岩井が，動物プランクトンは伊藤が夫々分担し，最後のまとめは伊藤が執筆した。この研究の大要は，日本陸水学会総会（昭 35，10 月，横浜）において口頭発表した。

II. 観測池の概況

観測は三重県安芸郡河芸町東千里にある丹羽篤郎氏所有の 3 面の汽水養魚池において行つた。これらの池は，田中川河口北部に位し，東並びに南側は海岸堤防を隔てて伊勢湾に膚接する。北東側は天然池，北西側は畑地に接する。(Fig. 1)

N_1 池はウナギ養殖池で，放養魚の大部分はウナギで，ボラを一部混養。面積は最も小さく，16.5 a，水深約 1 m，源水は池の北西隅にある掘抜井戸の地下水を使用しているが，注水量は極く少量である。底質は砂泥よりなり，水草は全く生えていない。

N_2 池は最も大きく，面積 263 a，水深平均約 1 m，放養魚の大部分はボラで，一部ウナギが混在，西南部の開水面で少量給餌。池の全面積の約 85% は *Potamogeton pectinatus*（リュウノヒゲモ）によつて被われ，水草の密度は 1.05 kg/m² (7 月 13日，風乾量）であつた。

N_3 池は最北部に位し，面積 68.8 a，水深平均約 1 m，池全面が *Potamogeton pectinatus* によつて被われ，開水面はない。水草の密度は 1.00 kg/m² （風乾量，7 月 13 日）である。放養魚の大部分はボラ，全く無投餌で自然に放置してある。N_1 池と N_2 池とは幅約 1 m の 2 個の水門で金網を通して連絡し，N_2 池と N_3 池とは幅約 1 m の 1 水路で連絡する。(Fig. 1).

N_1 池は 3 月 12 日から池替をはじめ，18 日に池水を完全に排水した。その後注水は行わなかつたが，池底からの滲出水が徐々に溜り，3 月 25 日，27 日に掘抜井戸から地下水を夫々深さ約 3 cm 宛注水し，28 日に N_2 池水を注入し満水した。その後 7 月 9 日の水変り時に N_2 池水と地下水を深さ約 15 cm 注水したのみで，その他はそのまま自然に放置した。しかし 8 月 13 日の台風による洪水が堤防をこえ，N_1，N_2，N_3 池の 3 池は 17 日まで完全に浸水し，池水は混合した。N_2 並びに N_3 池では池替は行わなかつた。

III. 観測方法

観測は昭和 34 年 3 月 19 日から 9 月 25 日にわたり，N_1，N_2，N_3 池の各定点 (Fig 1)

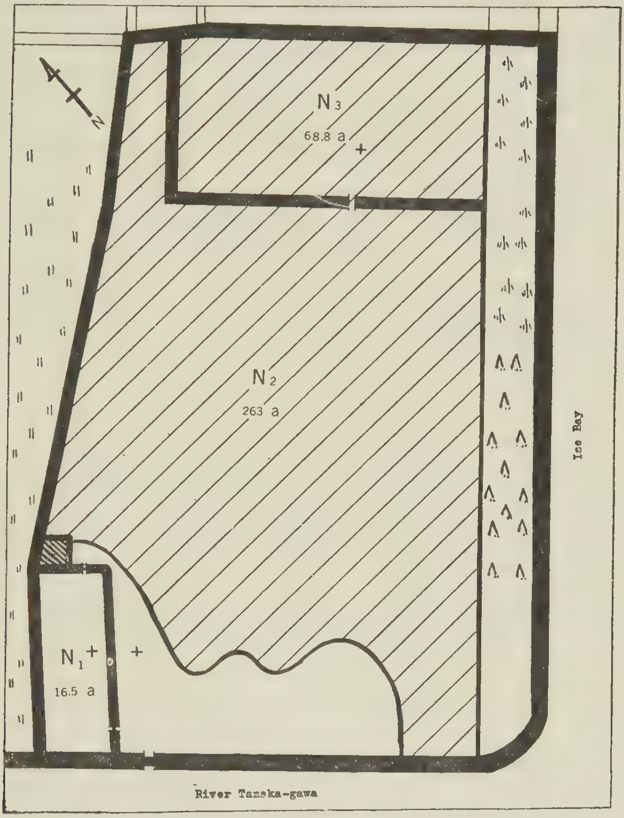

Fig. 1. Map showing the fish ponds, N_1 N_2 and N_3, Kawage-chô, Mie Prefecture, Middle Japan.

The mark, + shows the position where various surveys were made. The hatched area indicate the vegetation of *Potamogeton pectinatus*. N_1, the eel-culture pond in food supply; N_2 and N_3, weedy natunal fish ponds.

において，表層水について週 2 回の割合に行つた。観測時刻は午前 9 時～10 時である。9 月 26 日の伊勢湾台風によつて海岸堤防が決潰したのでその後の観測を打切つた。

水温は棒状寒暖計により，透明度は中村式透明度板を用い，pH は比色法，溶存酸素は Winkler の沃度滴定法（Alsferberg 変法），Cl は硝酸銀滴定法，Alkalinity は B.C.P. を指示薬として N/100 HCl により滴定し， NH_4–N は Watterberg 法，PO_4–P は Denigés-Atkins 法，NO_2–N は G.R. 試薬法，NO_3–N は Diphenylamine 法，Fe はロダンによる比色法を用いて夫々分析した。

動物プランクトンの定量には 2 つの方法を併用した。甲殻類等の大型プランクトンは，池水 10 l を xx16 のプランクトンネットで沪過し，フォルマリンで固定した材料について，輪虫類並びに纎毛虫類等の小型プランクトンは酸素瓶（約 100 cc）に採水し，フォルマリンで固定沈澱させ，上澄を棄却した材料について行つた。いずれも個体数計数法を適用し，4～5 cc に濃縮し，その中から駒込ピペットを用いて，液中に一様に分布させながら，液量の 1/8～1/10 を抽出し，計数盤に移し，その中に含まれる全個体を種類別に計

数し，池水 1l あたりの個体数として算出した。

植物プランクトンの定量には細胞計数法を適用した。池水を酸素瓶（容量約 100 cc）に採水し，フォルマリンを加えて固定し，約 1 週間静置し，完全に沈澱した後，更に遠心分離器（1500 回/分，5 分間）にかけて，1〜5 cc に濃縮し，ピペットによつて液中に一様に分布させるようにして，その一部を血球計算盤にとり，小区画 64〜400 個に含まれる植物プランクトンを種類別に計数し，池水 1 cc あたりの細胞数として算出した。

動物プランクトン並びに植物プランクトンの定量結果はすべて Lohmann の球曲線法を用いて図示した。

その他に N_1, N_2 池においては，4 月末，5 月末，7 月中旬，9 月中旬の 4 回，溶存酸素，pH の日週変化を，7 月 8 日には，N_1, N_2, N_3 池において植物プランクトン並びに水草の補償深度を測定した。これらの方法は後述する。

IV. 観　測　結　果

水草を欠き，投餌養殖中の養鰻池（N_1 池），水草が繁茂し開水面で少量投餌する粗放養魚池（N_2 池），全面水草に被われ開水面のない無投餌養魚池（N_3 池）の 3 面の汽水養魚池における水質，植物プランクトン，動物プランクトン，溶存酸素の日週変化，補償深度，水変り等の観測結果を比較対比して述べることにする。N_2 池並に N_3 池は一般に“天然池”と呼ばれ，N_1 池は“養殖池”と呼ばれている。

養殖池と天然池との比較

1. 水　質 (Figs. 2〜3)

水温：表層水温は気温の変化と並行的である。最高水温 31〜32°C はいずれも 8 月上旬に見られた。水温は全体的に見ると，3 池間に殆んど差異はない。(Fig. 2).

塩分：観測期間中の池水の塩分は，N_1 池では，Cl 4.8〜2.2‰，N_2 池では，3.6〜2.2‰ N_3 池では 3.2〜1.8‰ である。従つて全体的に見ると，これらの三池は，いずれも β 中鹹性汽水ないし α 貧鹹性汽水[6] に属する。塩分の季節的変化は Fig. 2 に明らかのように，N_1 池のみでは 3 月下旬に塩分は異常に大きいが，これは池替後における高鹹地下水の滲出のためである。4 月から 9 月にわたる 3 池の塩分変化の傾向は類似している。8 月中旬に塩分の急激な低下が 3 池に共通に見られるが，これは台風 7 号の洪水によることは前述した。全体的には池水の塩分は N_3 池が最も小さく，N_2 池と N_1 池とは大差はない。塩分の季節的変化は，8 月中旬の洪水の影響を除くと，軽微であると見做される。

アルカリ度：N_1 池では 2.3〜1.1 me/l, N_2 池では 2.2〜0.9 me/l, N_3 池では 1.8〜0.9 me/l で，N_1 池の池水のアルカリ度は N_2, N_3 の天然池よりやや大きい。しかし N_2, N_3 池間には著しい差はない。N_1 池では 3 月下旬の池替後に，塩分と同様に，アルカリ度の値も特に大きい。8 月中旬の豪雨時にはいずれも急激に低下した。全体的に見ると，3 池のアルカリ度は 1〜2 me/l で，顕著な差異はなく，かつその季節的変化も類似するといえよう。

透明度：池水の透明度は池によつて著しく異なる。N_1 池では最小 18 cm，最大 65 cm で，池底まで透視できる場合はなかつた。N_2 池は透明度の変化は相当大きく，5 月中旬から 6 月上旬にかけては，最小 40 cm を示したが，その他は殆んど池底まで透視され

た。この池では水草の繁茂帯と開水面では透明度は異なり，開水面では植物プランクトンの繁殖がよく水色も緑色を帯び，透明度も前述したように小さくなつたが，水草帯では植

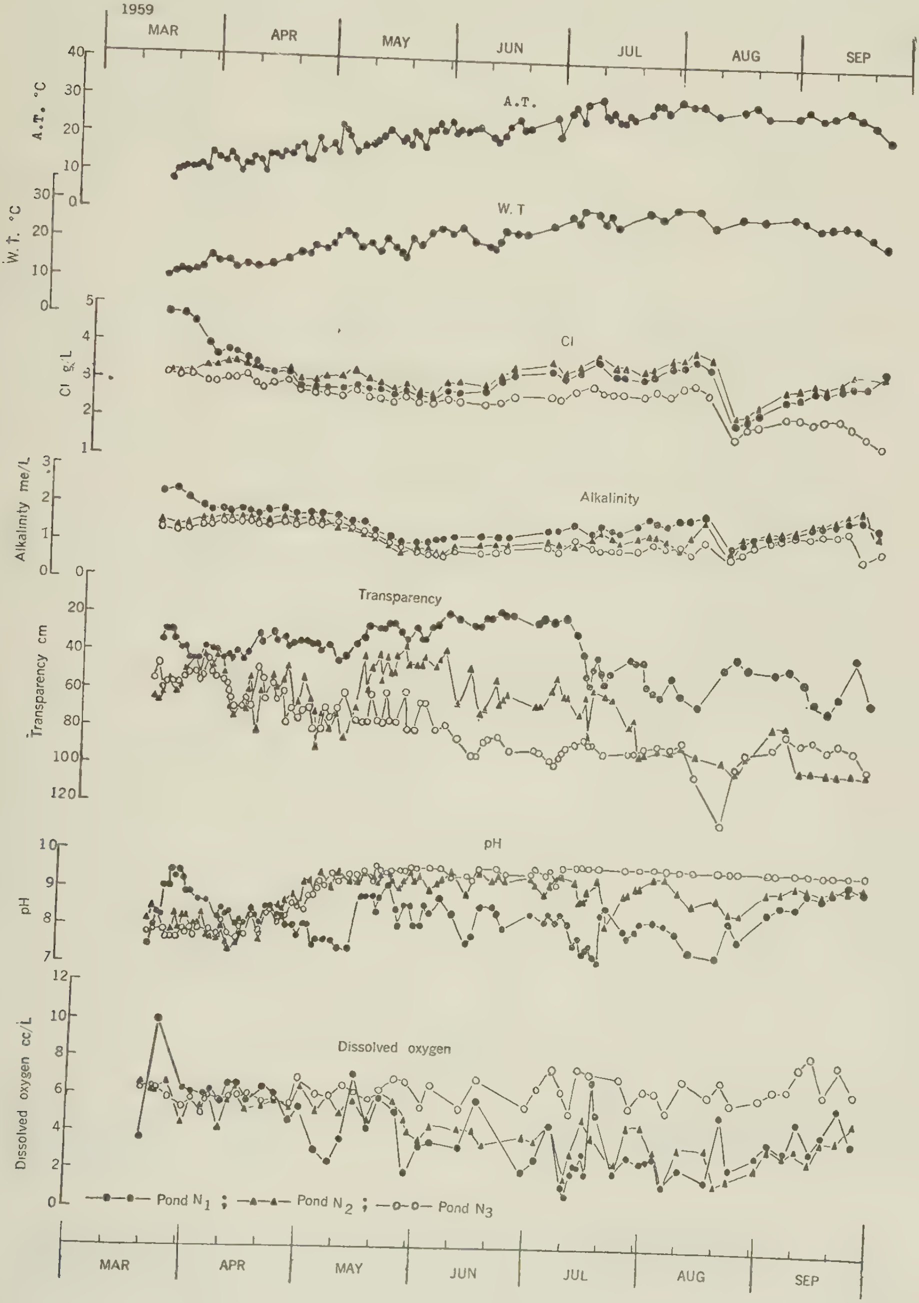

Fig. 2. The comparison of physico-chemical conditions between the eel-culture pond (N_1) and the weedy natural fish ponds (N_2 and N_3) in Kawage-chô, Mie Prefecture.

物プランクトンの増殖が悪く，池水は殆んど透明で，常に池底まで透視できた。N_3 池の透明度は N_2 池の水草帯と同じく，最小 48 cm に低下したこともあつたが，大部分は池底まで透視できた。従つて池水の透明度は養殖池（N_1 池）は常に他の 2 池より小さく，無投餌天然池（N_3）の透明度が最も大きく，少量投餌の開水面を有する天然池（N_2）は

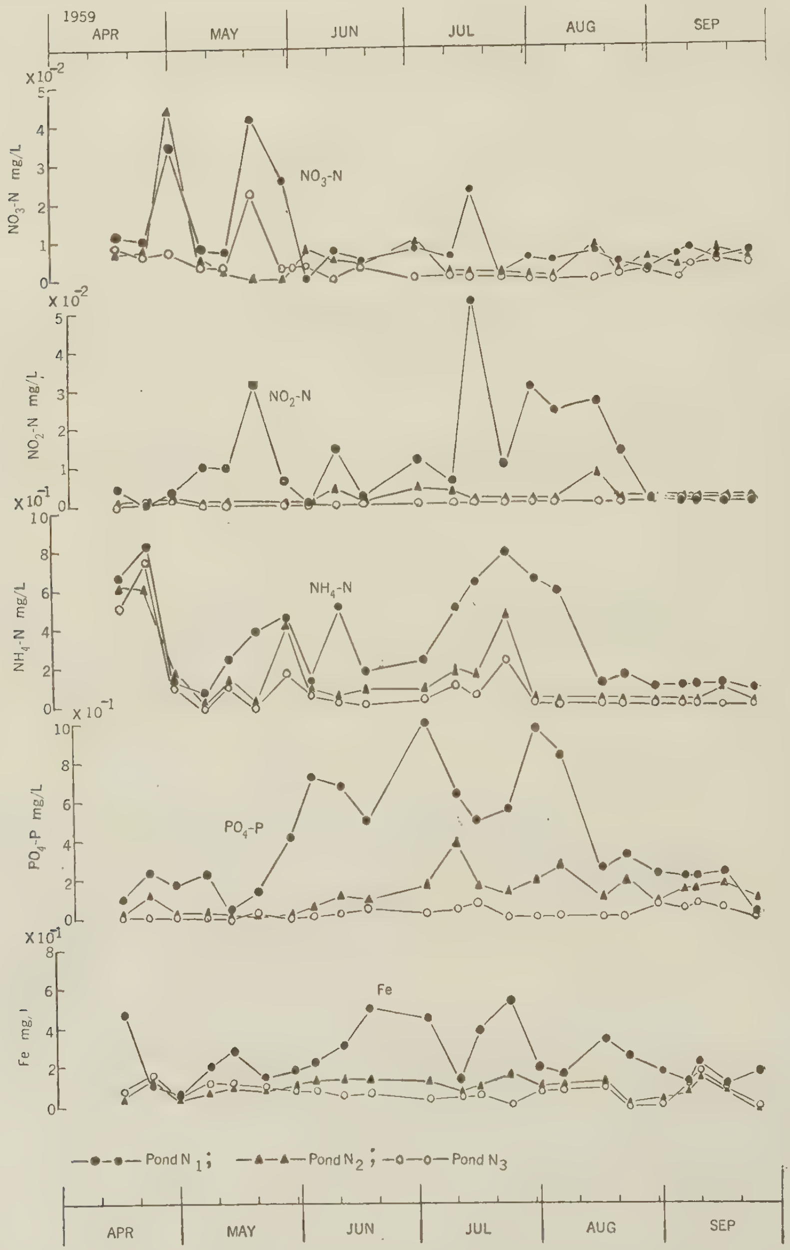

Fig. 3. The comparison of physico-chemical conditions between the eel-culture pond (N_1) and the weedy natural fish ponds (N_2 and N_3) in Kawage-chô, Mie Prefecture. (Continued).

両者の中間の透明度を示すといえよう。これは池水の透明度を支配する植物プランクトン量と並行的である。

池水の pH: 観測期間中の池水の pH の最高〜最低は, N_1 池では 9.5〜7.3, N_2 池では 9.7〜7.4, N_3 池では 9.8 以上〜7.7 であつた。

N_1 池の pH は, 3 月下旬〜4 月上旬には, 他の 2 池に比べ著しく高い。しかし 4 月中旬から逆に 2 池より低下し, その後の変動は相当に大きいが, 常に 2 池より低い。この差は日週変化 (Figs. 10〜11) にも明らかに認められる。N_2 ならびに N_3 池の池水の pH は, 4 月中旬から同様の傾向で上昇し, 5 月上旬から 9〜9.5 の平衡状態を保持し, 7 月上旬まで著しい変動はない。その後 N_2 池のみはやや低下したが, N_3 池では常に 9.8 以上を示した。従つて 5 月〜9 月には, 池水の pH は, 植物プランクトン量, 透明度とは逆に, N_3 池が最も高く, N_2 池がそれに次ぎ, N_1 池が最も低い。かつ pH の変動は逆に N_1 池が最も大きく, N_3 池が最も小さく, N_2 池は両者の中間である。

溶存酸素: 観測期間中の池水の溶存酸素の最大〜最小は, N_1 池では 10.5〜0.4cc/l, N_2 池では, 6.7〜1.5 cc/l, N_3 池では, 8.9〜5.0 cc/l で, 溶存酸素の変動は N_1 池が最も大きく, N_2 池がこれに次ぎ, N_3 池は最も小さく安定している。溶存酸素の季節的変化は Fig. 2 に明らかのように, 全体的に見ると, N_3 池の含有量が最も高い水準にあり, 比較的安定している。N_2 池と N_1 池ではともに変動が大きく, 特に N_1 池では著しく, 含有量の下限の低下も顕著である。従つて表層水の溶存酸素は *Potamogeton pectinatus* の密生した無投餌養魚池 (N_3 池) が最も含有量は多く, かつ変動も小さく, 常に高い水準にある。少量投餌で開水面の N_2 池ならびに投餌養鰻池 (N_1 池) では溶存酸素の変動が大きく, 特に N_1 池においては, 含有量の極限はさらに低下する。この点から見ると, 養殖魚に対しては, N_1 池が最も厳しい環境であるといえよう。また水変り池に対する注水の源水としては, N_3 池のように水草の生えた天然池の表層水は常に有利な条件を備えているといえよう。

栄養塩類: N_1, N_2, N_3 の 3 面の養魚池における NO_3-N, NO_2-N, NH_4-N, PO_4-P, Fe などの栄養塩類の含有量とその季節的変化は Fig. 3 に示してある。観測期間中におけるこれらの栄養塩類含有量の最大値は次の通りである。NO_3-N, は 0.04 (N_1 池) 0.04 (N_2 池), 0.02 (N_3 池) mg/l。NO_2-N はそれぞれ 0.06, 0.008, 0.001 mg/l。NH_4-N はそれぞれ 0.8, 0.6, 0.8 mg/l。PO_4-P はそれぞれ1.0, 0.4, 0.4 mg/l。Fe はそれぞれ 0.5, 0.2, 0.2 mg/l。これらの栄養塩類の季節的変化は Fig. 3 に明らかのように, 全体的に見ると, いずれの栄養塩類の含有量も, N_1 池が常に最も多く, N_2 池がこれに次ぎ, N_3 池は最小である。従つて投餌し, 地下水を注入する養鰻池 (N_1 池) が, N, P, Fe の含有量は常に最も大きく, 少量投餌, 開水面のある N_2 池がこれに次ぎ, 水草が繁茂し無投餌の N_3 池が最小であるといえよう。

2. 植物プランクトン (Table 1, Figs. 4〜6)

観測期間中に確認し得た植物プランクトンの種数は, N_1 池 30 種, N_2 池 22 種, N_3 池 18 種で, 養殖中の N_1 池が種類相は最も豊富で, 特に藍藻類, 緑藻類の種類が豊富である。少量投餌を行ない, 開水面のある N_2 池がこれに次ぎ, 水草が密生し, 開水面のない N_3 池が最も貧弱である。(Table 1)

これらの植物プランクトンの中で，量的にも，また季節的にも卓越した種類は Figs. 4～6 に明らかである。藍藻類の *Synechococcus* sp., *Chroococcus dispersus*, 緑藻類の *Selenastrum gracile*, 硅藻類の *Cyclotella glomerata*, *Cyc. Meneghiniana*, *Nitzschia closterium*, *Chaetoceros Muelleri* などが優占種としてあげられる。これらの優占種は 3 池に共通である。従つて植物プランクトン群集から見ると，N_1, N_2, N_3 の 3 池には著しい差異はない。上掲の植物プランクトンの優占種は，硅藻の *Cyclotella Meneghiniana*,

Table 1. The maximum standing crops of the phytoplankters in three fish ponds, N_1, N_2 and N_3. The figures show the cell numbers per ml.

Phytoplankters	Fish ponds		
	N_1	N_2	N_3
Cyanophyceas	$\times 10^4$	$\times 10^4$	$\times 10^4$
Synechococcus sp.	349.6	198.7	96.4
Chroococcus dispersus	74.7	24.7	21.5
Chr. minutus	13.4	1.4	13.7
Chr. limneticus	0.5		
Merismopedia tenuissima	+		
M. punctata	6.2		
Coelosphaerium Kuetzingianum	+		
Dactylococcopsis sp.	12.5		
Anabaena spiroides	tr.	tr.	tr.
A. sphaerica var. *tenuis*			1.6
Chlorophyceae			
Selenastrum gracile	65.9	7.6	9.2
Scenedesmus quadricauda	4.4	1.1	0.5
Sc. sp.	14.8		
Crucigenia rectangularis	6.0	4.3	
Dictyosphaerium pulchellum	0.5		
Ankistrodesmus falcatus spirilliformis	2.8	0.1	0.6
Coelastrum microporum	3.7	+	
Chlorella vulgaris	0.6	0.7	
Micractinium pucillum	+		
Oocystis spp.	3.8	1.0	2.4
Cryptomonas sp.	21.2	5.8	
Chlamydomonas sp.	7.4	1.2	1.9
Euglena sp.	0.5		
Diatoms			
Cyclotella Meneghiniana	1.1	tr.	0.3
Cyc. glomerata	27.4	26.2	24.0
Nitzschia closterium	10.1	24.1	2.0
N. sp.		tr.	tr.
Cocconeis sp.	tr.	tr.	tr.
Navicula sp.	tr.	0.9	tr.
Chaetoceros Muelleri	9.1	6.5	6.3
Ch. similis	3.8	1.0	1.0

Nitzschia closterium, *Chaetoceros Muelleri* を除いては，細胞の大きさは，2〜6μ で，いわゆる "micron-algae" に属する。従つて 3 池の植物プランクトンは "micron-algae" によつて代表されるといえる。

3 池における植物プランクトンの季節遷移は Figs 4〜6 に示した。優占種の *Synechococcus* sp., *Chroococcus dispersus*, *Selenastrum gracile*, *Cyclotella glomerata*, *Nitzschia closterium* などは持続性種に属し，3 月から 9 月にわたり連続的に出現し，水温に対する耐忍性のつよい種類であることが分る。この点動物プランクトンの季節遷

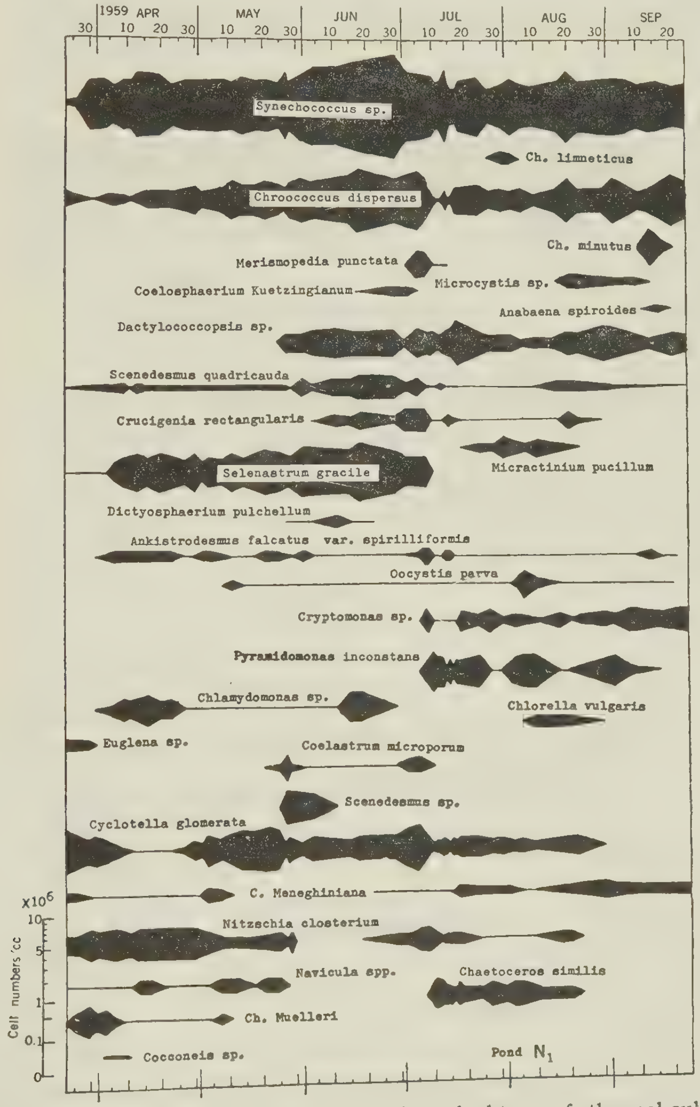

Fig. 4. The weekly successions of the phytoplankters of the eel-culture pond (N_1) in Kawage-chô, Mie Prefecture, from March to September of 1959. The figures illustrating with Lohmann's "Spherical curve method".

移と著しく異なつている。

3 月～9 月の観測期間中における植物プランクトンの各種類の standing crop の最大は Table 1 に掲げた。

また藍藻，緑藻，硅藻の 3 群に分けて，最大現存量を求めると，次のようになる。

種　類	養	魚	池
	N_1	N_2	N_3
藍　藻	350×10^4	199×10^4	96×19^4 cells/cc
緑　藻	78	8	9
硅　藻	30	27	24

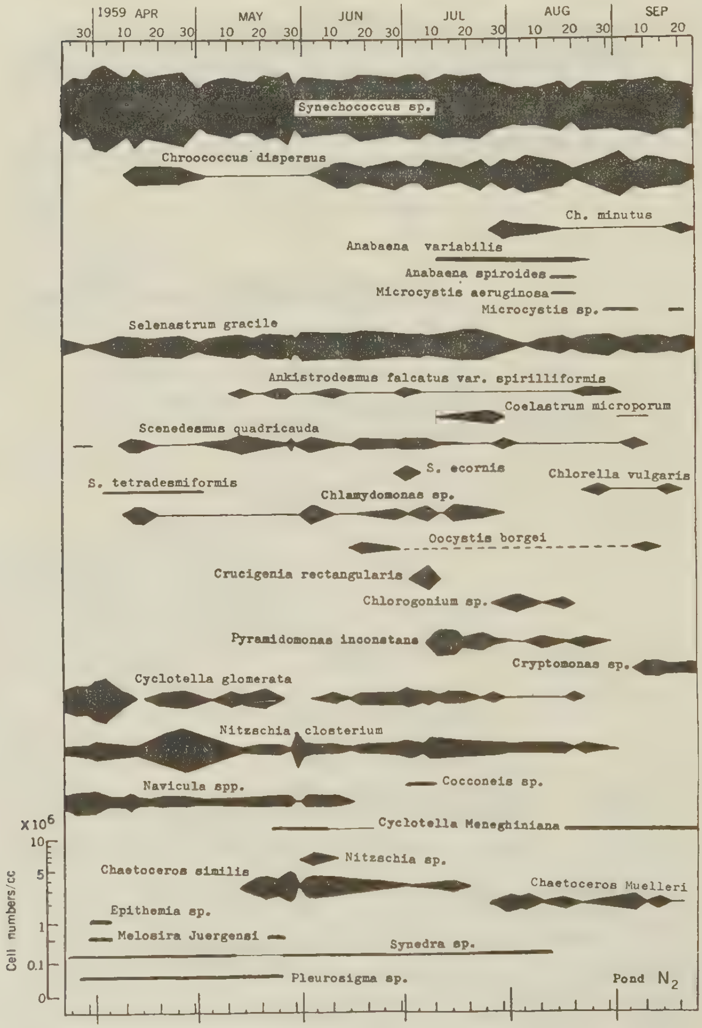

Fig. 5. The weekly successions of the phytoplankters of the weedy natural fish pond (N_2) in Kawage-chô, Mie Prefecture, from March to September of 1959. The figure illustrating with Lohmann's "Spherical curve method".

従つて，硅藻の最大現存量には 3 池で殆んど差はない。しかし藍藻，緑藻は池によつて著しく異なり，養殖池の N_1 池は水草の密生した天然池（N_2，N_3 池）に比し著しく大きく，緑藻は約 10 倍，藍藻は 2～4 倍を占めている。

すなわち養殖中の養鰻池では，藍藻，緑藻に属する micron algae が特によく増殖し，水草の生えた天然池においては，一般に硅藻類が卓越するといえよう。養殖池は天然池に比し，藍藻の最大現存量は 2～4 倍，緑藻は 10 倍であつた。

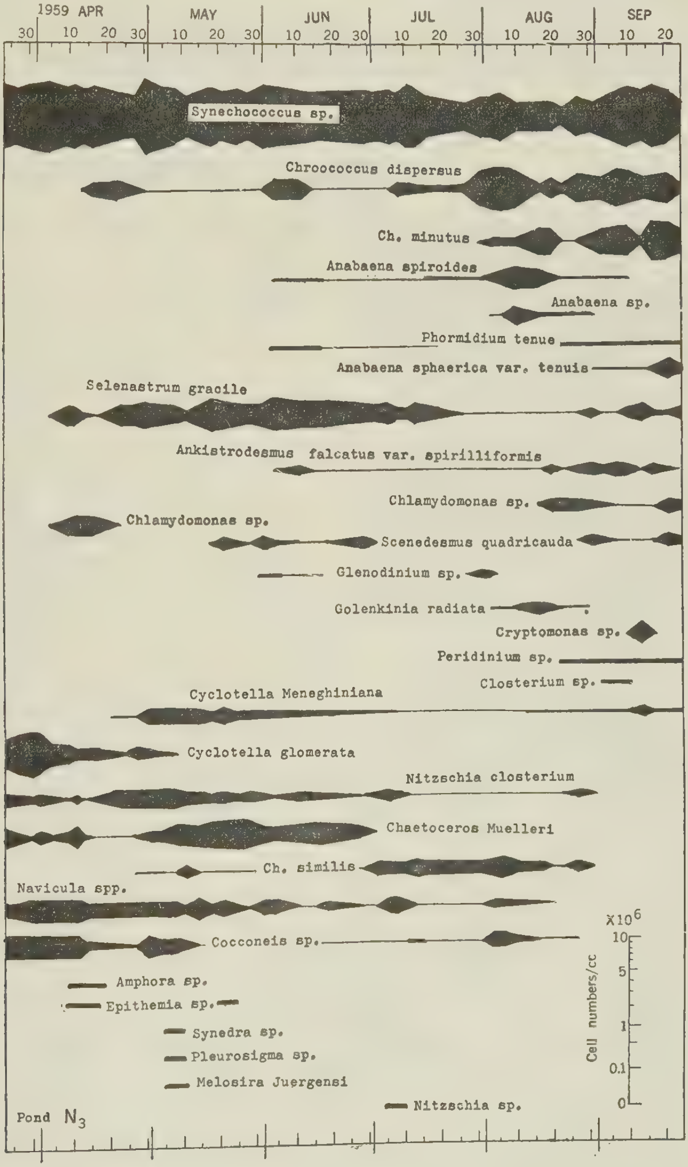

Fig. 6. The weekly successions of the phytoplankters in the weedy natural fish pond (N_3) in Kagage-chô, Mie Prefecture, from March to September of 1959. The figure illustrating with Lohmann's "Spherical curve method."

3. 動物プランクトン　(Table 2, Figs. 7〜9)

N_1, N_2, N_3 の 3 池で，3 月 19 日から 9 月 25 日の観測期間中にプランクトンネットで採集し得た動物の種類は Table 2 に掲げた。

水草を欠き投餌養殖中の N_1 池の動物プランクトンはすべて浮游性である。N_2 池の開水面の動物プランクトンは大部分が浮游性のもので，附着性種として *Alona rectangula* が見られ，他にこの池のみに *Acartia tsuensis*, *Oithona nana* が見られた。水草が密生し開水面のない N_3 池の動物プランクトンも大部分が浮游性に属するが，附着性種として *Alona rectangula*, *Monostyla* sp., イトトンボ幼生，キロノムス幼生がかなりの密度で出現した。従つて 3 池のプランクトン動物相はやや異なつている。しかし純粋の浮游性の動物プランクトン相は全体的に見ると，著しい差異はないといえよう。

3 池における動物プランクトンの季節遷移は Figs. 7〜9 に掲げた。季節遷移の様式は

Table 2. The maximum standing crops of zooplankters in three fish ponds, N_1, N_2 and N_3 in Kawage-chô, Mie Prefecture.
The figures indicate the number of individuals per 1.

Zooplankters	Fish ponds		
	N_1	N_2	N_3
Copepoda			
Acartia tsuensis		1	
Oithona nana		7	
Sinocalanus tenellus	109	44	109
Pseudodiaptomus inopinus	17	15	8
Paracyclopina nana	3461	8	60
Nauplius larva	437	170	96
Cladocera			
Alona rectangula		1	72
Rotatoria			
Brachionus quadridentatus	1600	80	80
Br. urceolaris	720	80	2
Br. angularis	3480	160	560
Keratella cruciformis eichwaldi	8	1	720
Br. plicatilis	45040	400	1280
Hexarthra fennica	10240	240	1040
Callidina sp.	1600	tr.	80
Filinia breviseta	19520	tr.	1120
Unknown rotifer	12080		
Notholca acuminata	tr.		
Diurella sp.	21220	720	5520
Monostyla sp.			1520
Larva			
Balanus nauplius	2		
Polychaeta larva	4		
Dragonfly's larva			14
Chironomid larva			tr.

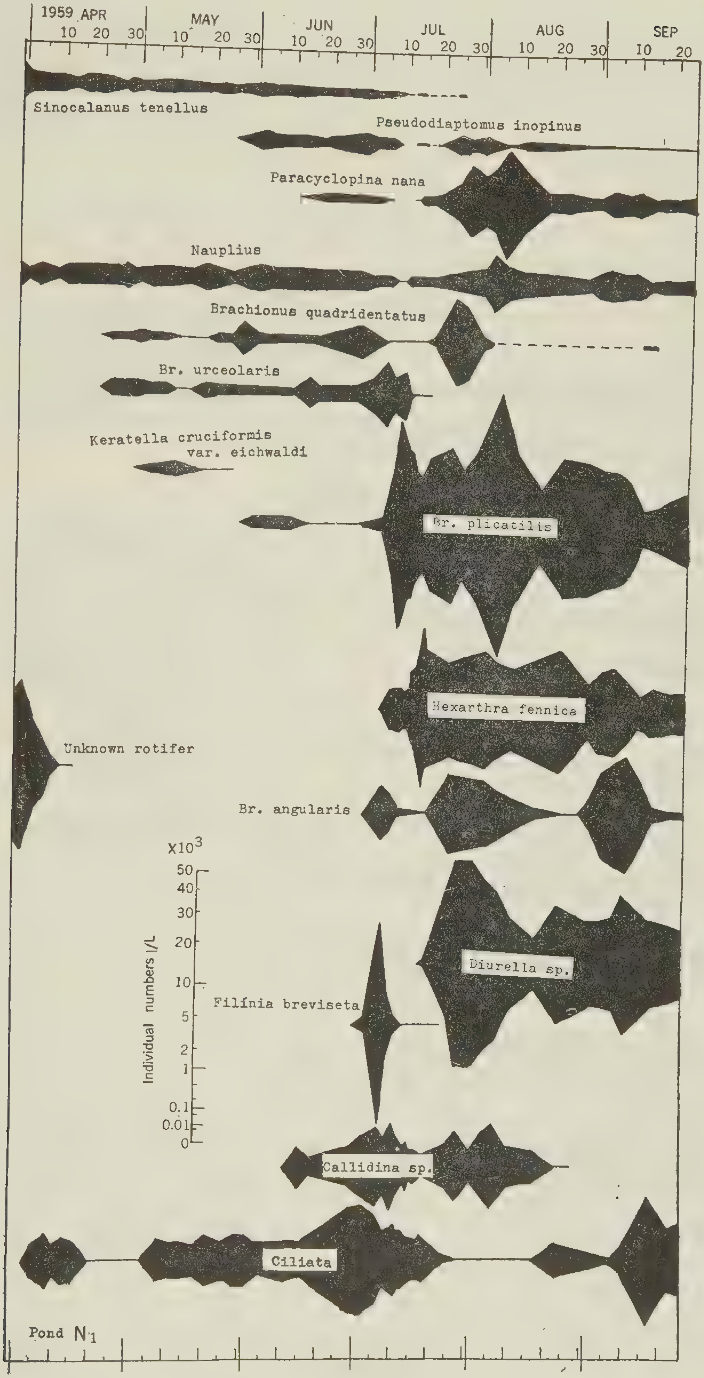

Fig. 7. The weekly successions of the zooplankters in the eel-culture pond (N_1) in Kawage-chô, Mie Prefecture, from March to September of 1959. The figure illustrating with Lohmann's "Spherical curve method".

大体一致している。橈脚類の *Sinocalanus tenellus* は 7 月には消滅し，*Pseudodiaptomus inopinus*, *Paracyclopina nana* と交替する。輪虫類の *Brachionus quadridentatus*, *Br. urceolaris*, *Keratella cruciformis* var. *eichwaldi* などは 4 月下旬～5 月上旬から出現し，*Keratella* は 5 月末，*Br. quadridentatus*, *Br. urceolaris* は 7 月には殆んど消滅し，*Br. plicatilis*, *Hexarthra fennica*, *Br. angularis*, *Filinia breviseta*,

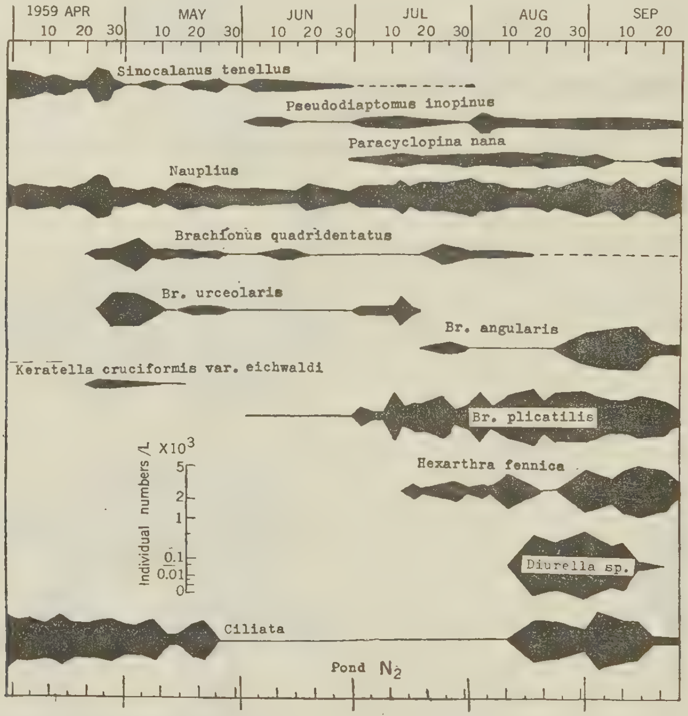

Fig. 8. The weekly successions of the zooplankters in the weedy natural fish pond (N_2) in Kawage-chô, Mie Prefecture, from March to September of 1959. The figure illustrating with "Spherical curve method."

Diurella sp. などと交替する。特にこれらの輪虫は 6 月下旬～7 月上旬からどの池においても飛躍的に増加した。

N_1, N_2, N_3 池における観測期間中の動物プランクトンの現存量を比較して見る。各池における各種の最大現存量を摘記すると，Table 2 のようになる。橈脚類，輪虫類の大部分の種において，養殖池（N_1 池）の方が天然池（N_2, N_3）に比べて現存量は著しく大きいことが分る。また動物プランクトンを甲殻類，輪虫類，繊毛虫類の 3 群に分けて，観測期間中におけるこれらの最大現存量（個体数）を求めると次のようになる。

種　　類	養	魚	池
	N_1	N_2	N_3
甲 殻 類	3568/*l*	174/*l*	122/*l*
輪 虫 類	58160	1280	7695
繊毛虫類	3040	400	160

従つて養殖池（N_1 池）の動物プランクトンの現存量は天然池（N_2, N_3）より顕著に大きく，甲殻類は 21～29 倍，輪虫類は 45～8 倍，繊毛虫類は 19～8 倍を示した。このことは最大現存量についてのみでなく，観測期間全体を通しても適用できる。(Figs. 7～9)

さらに重要なことは，養殖池（N_1）においては，汽水産輪虫 *Brachionus plicatilis* の耐久卵を持つた D♀ は 7 月 10 日から 9 月 3 日にわたり，この輪虫の増殖期にたびたび出現し，その最大密度は 2～5 個体/*l* であり，耐久卵の形成が明らかに認められた。これに対し，天然池の N_2 池では D♀ は 7 月下旬に僅かに出現し，N_3 池では全く見出し得なかつた。従つて養殖池においては *Br. plicatilis* の現存量は常に大きく，かつ耐久卵の形成も天然池（N_2, N_3）に比し著しく大きいといえよう。

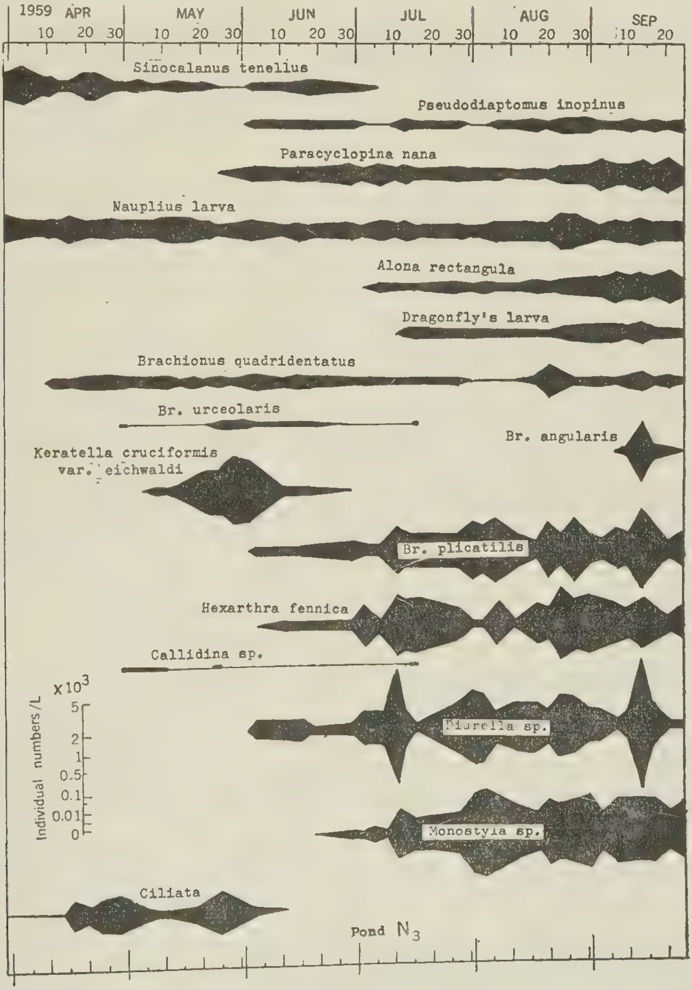

Fig. 9. The weekly successions of the zooplankters in the weedy natural fish pond (N_3) in Kawage-chô, Mie Prefecture, from March to September of 1959. The figure illustrating with "Spherical curve method."

4. 溶存酸素の日週変化

養殖池と天然池における溶存酸素と pH の日週変化の相異を明らかにするために，昭

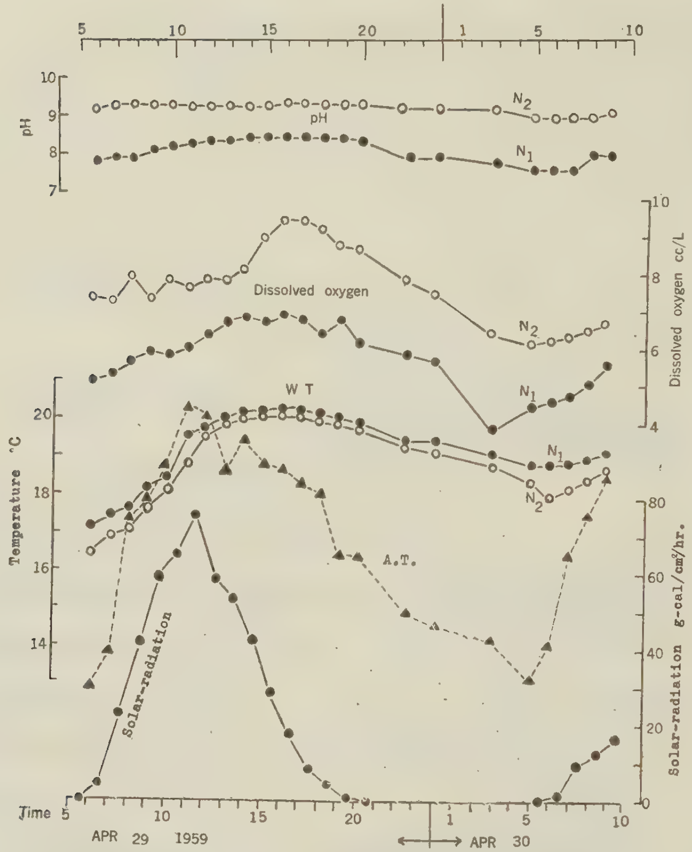

Fig. 10. The diurnal changes of dissolved oxygen and pH in the eel-culture pond (N_1) and the weedy natural pond (N_2), from Apr. 29 to Apr. 30, 1959.

和 34 年 4 月，5 月，9 月の 3 回，観測を行なつた。

a）第 1 次観測（1959 年 4 月 29 日～30 日，Fig. 10）

観測は，養殖池（N_1）と天然池（N_2）の開水面における各定点（Fig. 1）で表層水について行なつた。観測時のプランクトン相は，植物プランクトンの主成分は *Synechococcus* sp., *Chroococcus dispersus*, *Selenastrum gracile*, *Nitzschia closterium* で，相的には両池に差はなく，量的には養殖池が大きく，透明度は N_1 池は 40 cm，N_2 池は 63cm であつた。動物プランクトンの主成分は *Sinocalanus tenellus*, *Brachionus quadridentatus*, *Br. urceolaris* などで，両池に共通に見られたが，これらの密度はともに極めて小さい。

観測結果は Fig. 10 に示した。水温は N_1 池の方が常に若干高く，その差は早朝に大きい。従つて日較差は N_1 池が小さい。pH の日週変化はともに小さく，N_1 池では最高 8.5，最低 7.7，N_2 池では最高 9.4，最低 9.1 で日較差はさらに軽微で，かつ N_2 池が終日高い値を示した。溶存酸素の日週変化もともに顕著ではない。最大はともに 16～17 時に見られ，それぞれ 9.3 cc/*l*，6.8 cc/*l* を示し，最小は早朝の日の出前に見られ，それぞれ 6.1 cc/*l*，3.8 cc/*l* を示した。従つて日較差はともに約 3 cc/*l* であるが，N_2 池の溶存

酸素量は N_1 池より終日約 2 cc/*l* 多い。これは pH の日週変化と並行的である。

b) 第 2 次観測 (1959 年 5 月 29 日～30 日, Fig 11)

養殖池 (N_1) と天然池 (N_2) の開水面における各定点において表層水について観測した。観測時の植物プランクトンの主成分は, N_1 池では *Synechococcus* sp. (35.8×10⁴cells/cc), *Chroococcus dispersus* (13.6×10⁴), *Selenastrum gracile* (9.6×10⁴), *Cyclotella glomerata* (5.6×10⁴) で, 透明度 25 cm。N_2 池では *Synechococcus* sp. (47.8×10⁴ cells/cc), *Nitzschia closterium* (11.1×10⁴), *Selenastrum gracile* (4.1×16⁴), *Chaetoceros Muelleri* (4.9×10⁴) などで, 透明度は 52 cm で大きい。動物プランクトンの主成分はともに *Sinocalanus tenellus*, *Br. quadridentatus*, *Br. urceolaris* で, その密度は極めて小さい。

観測結果は Fig. 11 に示した。水温の日週変化は, N_1 池では最低 22.5°C, 最高 26.7°C, 日較差 4.2°C, N_2 池では最低 22.5°C, 最高 27.3°C, 日較差 4.8°C で, 第 1 次観測とは逆に最高水温は N_2 池の方が高い。最低水温はともに5～7時に見られ, 最高水温は 16～17 時に見られる。池水の pH の日週変化は, N_1 池では最低, 7.5, 最高 9.3, 日較差 1.8, N_2 池では最低 9.3, 最高 9.7, 日較差は 0.4 であつた。従つて pH の日週変化は N_2 池は極めて軽微で, かつ終日9.3以上を保つた。しかし N_1 池では日変動は大きく, 最高は 16～17時に見られる。溶存酸素の日週変化は, N_1 池では, 最低 1.2 cc/*l*, 最大 8.0 cc/*l*, 日較差 6.8 cc/*l*, N_2 池では最低 3.7 cc/*l*, 最大 7.9 cc/*l*, 日較差 4.2 cc/*l* であつた。従つて日変動は N_1 池の方が大きく, 最大酸素量には差がないが, 夜間の酸素消費は N_1 池の方が大きい。最低はともに5～6時に, 最大はともに16～17時に見られ, 両池に差はない。

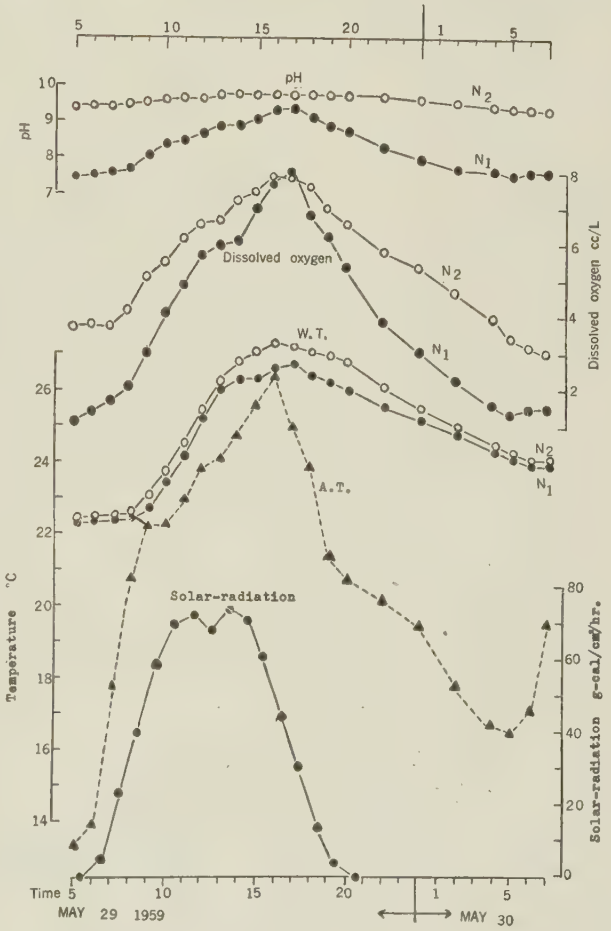

Fig. 11. The diurnal changes of dissolved oxygen and pH in the eel-culture pond (N_1) and the weedy natural fish pond (N_2) from May 29 to May 30, 1959.

c) 第 3 次観測 (1959 年 9 月 20 日～21 日, Fig. 12)

第 1 次ならびに第 2 次観測においては, N_2 池では開水面の定点で行なつたので, 溶

存酸素，pH の日週変化は N_1 池のそれに類似し，水草の影響がどの程度関与しているのかはつきりしなかつたので，本観測においては，*Potamogeton pectinatus* の密生した開水面のない N_2 池のほぼ中央部（水深 125 cm）の 1 点において，一方，養殖池（N_1 池）は第 1 次・第 2 次観測と同じ点において日週変化を調べた。上述の各定点において，西牧式注射器を利用して，表層，25 cm，50 cm，75 cm，底層（池底から 5 cm 上方，N_1 池は 100 cm，N_2 池は 120 cm）の 5 層から採水し，溶存酸素，pH を測定した。水温は各池の表層水のみについて測定した。

観測時の N_1 池の環境条件は次の通りである。植物プランクトンの主成分は *Synechococcus* sp. (21.8×10^4 cells/cc), *Chroococcus dispersus* (44.2×10^4), *Dactylococcopsis*

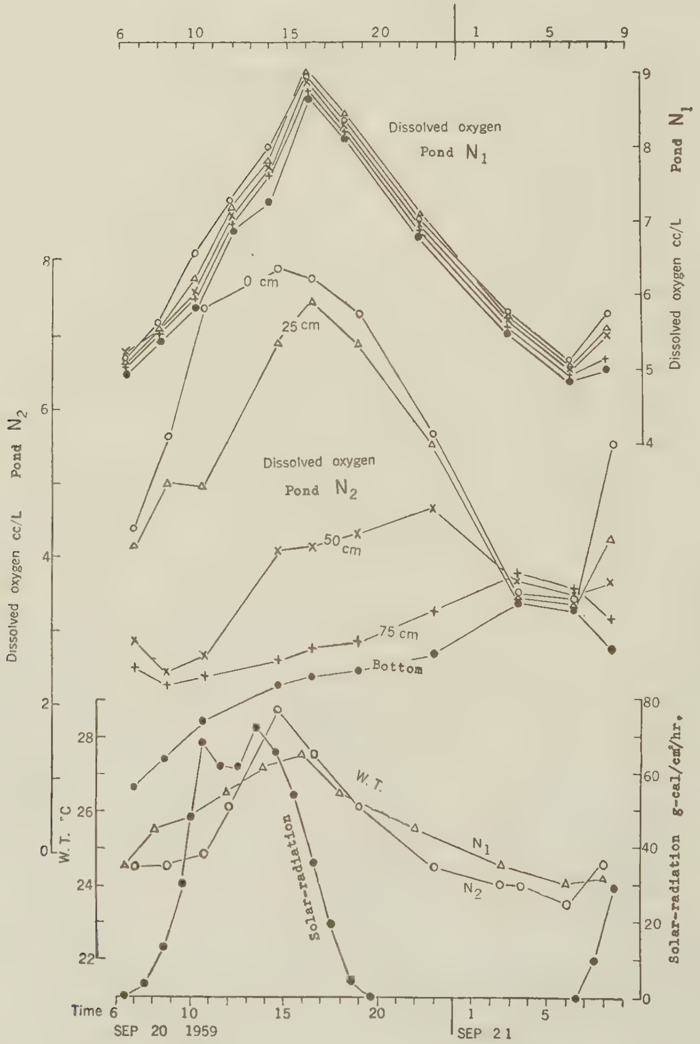

Fig. 12. The diurnal changes of the vertical stratification of dissolved oxygen in the eel-culture pond (N_1) and the weedy natural pond (N_2), from September 20 to 21, 1959.

sp. (3.2×10^4) で，透明度は50 cm。動物プランクトンの主成分は *Paracyclopina nana*, *Br. plicatilis*, *Hexarthra fennica*, *Diurella* sp. などで，その個体数密度は，甲殻類 3 個体/*l*，輪虫類 1720 個体/*l*，繊毛虫類 960 個体/*l* で，これらの密度は普通で大きくはない。N_2 池の植物プランクトンの主成分は N_1 池と同じく，*Synechococcus* sp., *Chroococcus dispersus* であるが，その量は 15.5×10^4 cells/cc で，N_1 池より小さく，透明度も大きく，水草の間から池底（125 cm）を透視できた。水面は *Potamogeton pectinatus* によつて一面被われている。

観測結果は Fig. 12 に示した。表層水温の日週変化は，N_1 池では最低 24°C，最高 27.5°C，日較差 3.5°C，N_1 池では最低 23.5°C，最高28.7°C，日較差 5.2°Cで，N_2 池の方が最高水温は高く，かつ日変動も大きい。しかし最高水温はともに 15 時頃に見られ，最低は 6 時頃に見られ，この点は一致する。溶存酸素の垂直分布の日週変化には両池に著しい相違が見られた。N_1 池では溶存酸素の成層は顕著でなく，上下層殆んど同じで，その日週変化も同じであつた。最大は 16 時頃に 8.7～9.2 cc/*l* に達し，最低は 6 時（21 日）に見られ，4.8～5.1 cc/*l* を示し，日較差は約 4 cc/*l* である。これに反し，N_2 池においては溶存酸素の垂直的成層が極めて顕著で，日射量の増大とともに，0～25 cm 層の溶存酸素は急激に増加し，表層では 15 時に最大 7.9 cc/*l*，25 cm 層では 16 時頃に最大 7.5 cc/*l* に達し，その後は急激に減少した。しかし，50，75，120 cm 層では溶存酸素は徐々に増加し，この増加は 0～25 cmの表層水の溶存酸素の減少にもかかわらず認められた。しかし翌朝 4～6 時に全層殆んど同じ値になつた。池水の pH には溶存酸素のように著しい日週変化ならびに垂直的成層は見られなかつた。N_1 池では朝は全層 9.3～9.4 であつたが，日中には 0～50 cm 層では 9.8 に上昇，75 cm 層では 9.6，底層（100 cm）では 9.5 であつた。N_2 池では pH は N_1 池より高く，1 日中 9.4～9.8 以上を示し，かつ N_1 池より成層は明瞭であつた。

d）要約

N_2 池の開水面と N_1 池における溶存酸素と pH の日週変化を比較すると，植物プランクトン量の多い養殖池（N_1 池）が日変動も大きく，かついずれも終日低い水準にあつた（第 1 次・第 2 次観測）。N_2 池の水草の密生帯と N_1 池における溶存酸素の垂直分布とその日週変化は著しく異なる。水草帯では溶存酸素の垂直成層が顕著で，0～25 cm 層の日週変化は大きいが，50 cm 以深の変化は極めて小さく，日週変化の様式は層によつて異なつている。他方，養殖池（N_1 池）では垂直成層はなく上下層殆んど同じで，かつ日週変化の様式もほぼ等しい。この両池における溶存酸素の垂直分布の差は，水草の有無，養殖魚の活動程度に依存すると考える。養鰻池においては一般に“水変り”時には，天然池の池水を注入している。この場合溶存酸素の点からは，天然池の表層水を用いるのがより有効であろう。

5. 補償深度 (Table 3, Fig. 13)

水草を欠き，植物プランクトンのよく増殖した養殖池（N_1 池）と水草の密生した N_2 池の開水面，水草に被われた天然池（N_3 池）における植物プランクトンと水草の緑色植物の補償深度を明らかにするために，3 面の池で昭和 34 年 7 月 8 日に調査を行なつた。調査時における各池の環境条件の大要は次の通りであつた。

環境条件	養魚池 N_1	養魚池 N_2	養魚池 N_3
養殖魚	ウナギ 養殖池	ボラ（ウナギ） 天然池	ボラ 天然池
給餌	多量	少量	なし
水草	なし	多量	多量
水深	80 cm	80 cm	85 cm
植物プランクトン			
Synechococcus sp.	88.0×10^4/cc	38.0×10^4/cc	24.6×10^4/cc
Chroococcus dispersus	32.0	6.9	0.6
Selenastrum gracile	11.3	2.4	0.6
動物プランクトン			
甲殻類	tr.	tr.	tr.
輪虫類	23200/*l*	tr.	tr.
繊毛虫類	560/*l*	tr.	tr.

植物プランクトンの主成分には 3 池で差はないが，量的には N_1 池が圧倒的に大きく，N_2，N_3 池は小さい。動物プランクトンは N_1 池は“水変り”直前にあり，特に輪虫類の個体数密度が大きい。

植物プランクトンの補償深度と酸素消費量は，各池水（表層水）をそのまま酸素瓶（容量約 100 cc）に封入し，各池の表層，20 cm，40 cm，60 cm，80 cm の 5 層に水平に吊し，午前 9 時から 12 時まで 3 時間（名古屋における日射量は 9〜10 時, 55; 10〜11 時, 36, 11〜12 時，55 g-cal/cm²/hr.）放置して決定した。

水草（*Potamogeton pectinatus*）は，N_2 池から水面近くにある先端部を採葉，各 1 g（湿重量）を酸素瓶に入れ，N_3 池水を満たして，植物プランクトンと同様にして，N_3 池の水草の密生帯の 5 層に水平に吊してこれも 3 時間放置して決定した。この場合，水草の容積，植物プランクトンによる影響を補正した。

植物プランクトンならびに水草の呼吸量を知るために，黒瓶を各池の 20 cm 層と底層に各 1 本づつ 3 時間おき，白瓶と同様にして溶存酸素量を決定した。

測定結果は Table 3 に示した。各池の植物プランクトンを酸素瓶に封入し，表層〜20 cm に吊した場合の溶存酸素の 3 時間後の増加量を比較すると，N_1 池では，9.29〜9.40 cc/*l*，N_2 池では，2.13〜3.14 cc/*l*，N_3 池では 0.02〜0.09 cc/*l* となり，N_1 池が最大で，N_2池がこれに次ぎ，N_3池では最も小さい。これは各池の植物プランクトンの現存量と並行している。呼吸作用による酸素量の減少を比較すると，N_1池では −1.07 cc/*l*/3 hrs.，N_3 池では −0.35 cc/*l*/3 hrs. で，N_2 池では測定しなかつた。

水草（*Potamogeton pectinatus*）の炭酸同化作用による溶存酸素の増加量は表層〜20cm 層では 2.10〜2.37 cc/*l*/3 hrs./g（湿重量）で，一方，呼吸作用による減少量（1g, 3 hrs.）は −6.46 cc/*l* を示し，植物プランクトンに比べて，炭酸同化による酸素の生成に対する呼吸による酸素消費が *Potamogeton* は大きいといえよう。

N_1，N_2，N_3 池における各池の植物プランクトンの補償深度，ならびに N_3 池における

Table 3. Oxygen productions of phytoplankton and *Potamogeton pectinatus* in three fish ponds, N_1, N_2 and N_3 observed within the time of 3 hours on July 8, 1959.

N_1: eel-culture pond, transparency 27 cm; N_2: open water of weedy natural pond, trans. 65 cm; N_3: weedy natural pond, trans. 85 cm.

Ponds	Depth (cm)	Initial O_2 cc/l	O_2 cc/l after 3 hrs.	O_2 cc/l changed	
Phytoplankton					
N_1	0	2.86	12.15*	+9.29	white bottle
	20	〃	12.26*	+9.40	〃
	40	〃	5.74	+2.88	〃
	60	〃	3.20	+0.34	〃
	80	〃	2.49	−0.37	〃
	20–80	〃	1.79	−1.07	black bottle
N_2	0	2.55	4.68	+2.13	white bottle
	20	〃	5.69	+3.14	〃
	40	〃	5.37	+2.82	〃
	60	〃	4.41	+1.86	〃
	80	〃	3.00	+0.45	〃
N_3	0	7.16	7.18	+0.02	white bottle
	20	〃	7.25	+0.09	〃
	40	〃	7.07	−0.09	〃
	60	〃	7.04	−0.12	〃
	80	〃	6.99	−0.17	〃
	20–80	〃	6.81	−0.35	black bottle
Potamogeton pectinatus					
N_3	0	7.16	9.26*	+2.10	white bottle
	20	〃	9.53*	+2.37	〃
	40	〃	7.12	−0.04	〃
	60	〃	4.73	−2.43	〃
	80	〃	2.99	−4.17	〃
	20–80	〃	0.70	−6.46	black bottle

The mark, * indicates the excess bubble of oxygen.

水草 (*Potamogeton pectinatus*) の補償深度は Fig. 13 に示した。N_1 池の植物プランクトンの補償深度は約 68 cm にあり，透明度（27 cm）の約 2.5 倍に相当する。N_2 池の水草のない開水面における植物プランクトンの補償深度は池底（80 cm）より深いところにあり決定されなかつた。N_3 池の水草に被われ，開水面がなく，水草帯の中で測定した植物プランクトンならびに水草の補償深度は大体一致し，約 40 cm 位にある。この池の透明度は 80 cm 以上であるから，N_3 池における緑色植物の補償深度は極めて浅いところにあるといえる。これは密生した水草によつて日光が遮断される結果であることは明らかである。

この観測結果によると，水草の密生による日光遮断の影響は，植物プランクトンの増殖

による濁り以上に大きいといえよう。

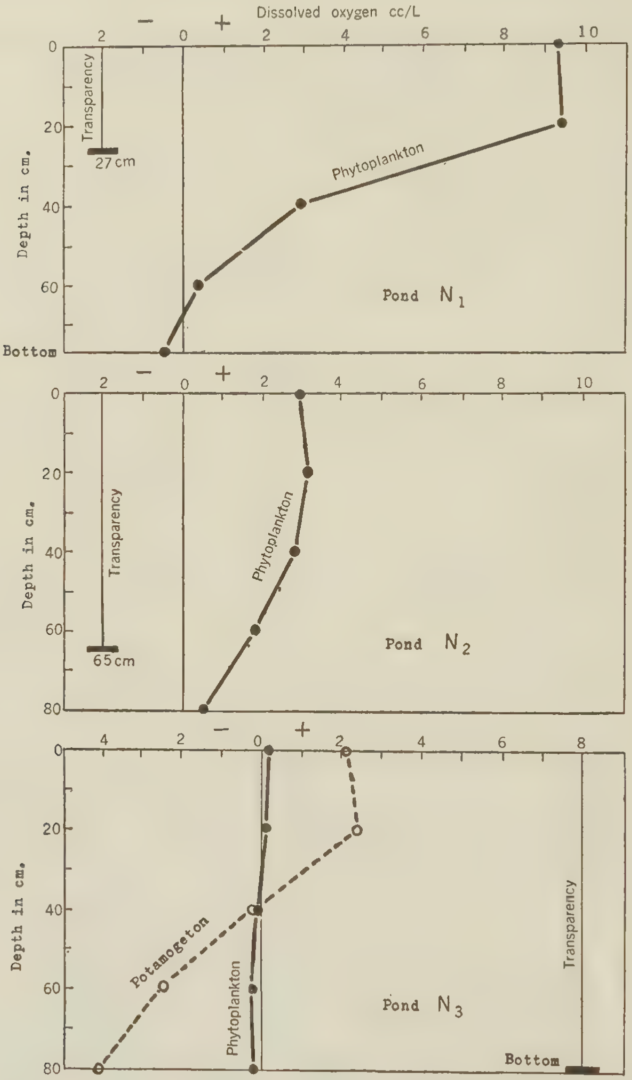

Fig. 13. The compensation depths in three fish ponds, N_1, N_2 and N_3. Date: July, 8, 1959. Dominant species of phytoplankton in three ponds: *Synechococcus* sp. and *Chroococcus dispersus*.
Potamogeton: *P. pectinatus*.

6. "水変り" について (Fig. 14)

養殖池（N_1 池）において，観測期間中に 2 回の"水変り"が見られた。その実態は次の通りである。

1)　第 1 次水変り（1959 年 7 月中旬）

7 月 6 日頃までは，*Synechococcus* sp., *Chroococcus dispersus* などの micron-algae がよく増殖し，透明度は 20 cm 前後，溶存酸素は 5 cc/l, pH は 8.5 を示し，池は好調で

あつた。しかし植物プランクトンは 7 月 8 日から減少しはじめ，10 日には 1/2 に，11 日には 1/3 に，12 日には 1/5 に減少し，これに伴ない，池水の透明度は急激に増大し，12 日には 56 cm の最大となり，溶存酸素も水変りの最盛時には 0.4 cc/*l* に減少，pH も 7.3 に低下した。この水変りに消費者としての輪虫類の異常増殖が見られた。7 月 8 日から *Brachionus plicatilis* が *Filinia breviseta* に代つて大増殖をはじめ，10 日に最大密度 23 個体/cc に達した。従つてこの水変りは *Br. plicatilis* の大増殖とその植物プランクトンの捕食作用によつて説明できる。この水変りにおける養殖魚の被害は，7 月 8 日の夜半から 9 日の早朝にかけて，ボラ約 300 kg，ウナギ約 15 kg が斃死し，その後 16 日まではウナギの餌付皆無，18 日から餌付はやや良好となり，水変りは回復した。

この水変りの最盛時（7 月 11 日〜12 日）における溶存酸素，pH の日週変化（表層水）は Fig. 14 に掲げた。溶存酸素は 11 日の夜間には徐々に減少する傾向があり，午前 3 時 30 分には最低 0.4 cc/l を測定した。かつ水車による aeration によつて池水中の溶存酸素は僅かではあるが増加し，効果的であることが分る。日の出とともに溶存酸素ならびにpHは上昇した。しかし正常時の水準には達しなかつた。

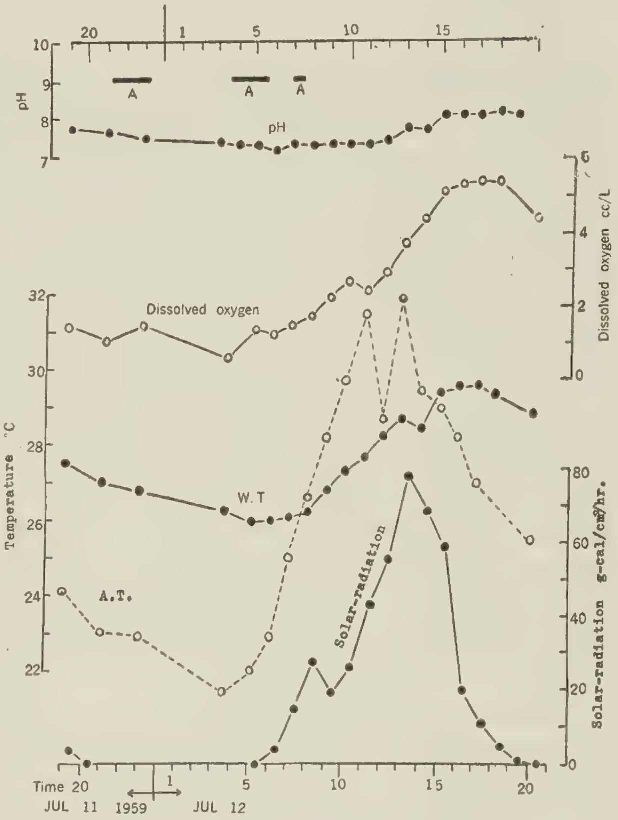

Fig. 14. The diurnal changes of dissolved oxygen and pH in the time of "Mizukawari" of the eel-culture pond (N_1).

Date: July 11–12, 1959. The marks, A show the aeration with an electric water-mill.

2) 第 2 次水変り（7 月 31 日〜8 月上旬）

第 1 次水変りは 7 月18日頃から回復し，ウナギの餌付も好転したが，7 月末より第 2 次水変りとなり，餌付は再び皆無となり，8 月 6 日早朝には鼻上げが見られた。しかし斃死は見られないので軽度の水変りといえる。この水変りには，汽水産輪虫 *Brachionus plicatilis* の大増殖が伴ない，8 月 6 日には最大密度 58 個体/cc に達し，かつ橈脚類の *Paracyclopina nana* の増殖も見られ，3461 個体/l の最大密度に達した。一方，植物プランクトンの優占種 *Synechococcus* sp. が減少したが消滅には至らず，第 1 次水変りに比し減少は小さい。また透明度は 49 cm から 64 cm に増大，溶存酸素は 6 日に最小 1.5 cc/l に低下したが，早朝

にはさらに減少したものと考える。pH は徐々に最低 7.6 に達した。

この水変り時における輪虫の最大密度は大きいが，水変りの程度は，第 1 次水変りに比べて小さい。

N_1 池においては前述の 2 回の水変りがおこり，養殖魚に被害が見られたが，天然池の N_2, N_3 池にはいずれも全く水変りは認められず，養殖魚の異常は観察し得なかつた。

また 8 月 13 日の台風 7 号の豪雨によつて，3 池の塩分は急激に Cl 3～3.9‰ から Cl 1.8～2.2‰ となり，約 1/2 に低下し，またアルカリ度も 2 me/l から 1 me/l となり，これも 1/2 に低下した。しかし植物プランクトン，動物プランクトンの両相には殆んど変化は見られていない。従つてこの程度の塩分低下によつては，前述の 3 池のプランクトンは全く影響を受けないといえよう。

7. 養殖魚の成長

養殖池と天然池における養殖魚の成長を比較するために，主として天然餌料に依存するボラを対照とし，3 月に田中川河口で採捕したボラの稚魚を，N_1, N_2, N_3 池に分けて放養し，冬期の池替期に取り上げ，その成長度を比較するとともに，食性調査の計画を樹てた。しかしこの計画は，8 月 13 日の台風 7 号の豪雨によつて 3 池が冠水し，かつ 9 月 26 日の伊勢湾台風によつて海岸堤防が決潰し，海水が流入し，養殖魚は混合し，かつ流失したので，挫折に至つた。従来の経験結果によると，N_1 池のボラの成長は N_2 池より著しくよく，約 2 倍以上といわれている。

V. 総　　括

給餌養殖中の養鰻池 (N_1 池)，池面の 85% が大型水生植物 (*Potamogeton pectinatus*) に被われ，少量給餌の天然池 (N_2 池) の開水面，全面水草が密生し，無給餌の天然池 (N_3 池) の 3 面の汽水養魚池において，昭和 34 年 3 月 19 日から 9 月 25 日にわたり，水質，植物プランクトン，動物プランクトン，溶存酸素の垂直分布とその日週変化，補償深度，水変りなどについて観測し，比較した結果は次のように総括できる。

水質: 表層水温は気温変化と並行し，3 池に著しい相違はなく，8 月上旬に 31～32°C の最高水温が見られた。池水の塩分は N_3 池が最も小さく，N_1 池がこれに次ぎ，N_2 池は N_1 池よりやや大きい。しかし全体的には，β 中鹹性汽水ないし α 貧鹹性汽水[6] に属し，かつ季節的変化も類似する。池水のアルカリ度は 1～2 me/l で，3 池に顕著な差はなく，その季節的変化もほぼ同じである。透明度は植物プランクトンの現存量によつて著しく異なり，N_1 池は最小 18 cm, N_2 池の開水面では最小 40 cm, N_3 池は最も澄み，常に池底 (約 100 cm) を透視できた。表層水の pH は植物プランクトン量ならびに透明度とは逆に，一般に N_3 池が最も高く，かつ安定し，N_2 池がこれに次ぎ，N_1 池が最も低く，かつ季節的，時間的変動が大きい。表層水の溶存酸素量も pH と並行し，N_3 池が季節を通じて最も高い水準にあり，かつ変動も小さい。N_1 池は最も変動が大きく，最小量の低下も顕著である。N_2 池は含有量，変動性ともに両池の中間に位する。NO_3–N, NO_2–N, NH_4–N, PO_4–P. Fe などの栄養塩類の含有量は，常に N_1 池が圧倒的に大きく，N_2 池が，これに次ぎ，N_3 池は最小である。この差は給餌量の有無，多少が大きく支配していると考える。

植物プランクトン: 種類相は N_1 池が最も豊富で，特に藍藻類，緑藻類が卓越し，N_2

池がこれに次ぎ, N_3 池が最も貧弱である。しかし *Synechococcus* sp., *Chroococcus dispersus*, *Selenastrum gracile*, *Cyclotella glomerata*, *Nitzschia closterium* などの micron-algae がどの池においても優占種であり，かつ季節的にも卓越し持続性種に属し顕著な季節遷移は見られない。植物プランクトンの最大現存量は，硅藻類は3池に差はない。藍藻類ならびに緑藻類の現存量は，N_1 池が最大で他の N_2, N_3 池のそれぞれ 2～4 倍，10 倍を示した。従つて養殖池は水草の密生した天然池に比べて，植物プランクトン，特に micron-algae に属する緑藻ならびに藍藻の生産量が顕著に大きい。

動物プランクトン: 3 池の種類相は全体的には同じであり，水草の繁茂した天然池には若干の水草附着性種が混在する。動物プランクトンの季節遷移も一致し，輪虫類は6月末～7 月上旬から急激に増殖する。優占種としては *Sinocalanus tenellus*, *Pseudodiaptomus inopinus*, *Paracyclopina nana*, *Brachionus plicatilis*, *Hexarthra fennica*, *Dinrella* sp. *Br. angularis* を挙げられる。甲殻類，輪虫類，繊毛虫類の最大現存量は，いずれも N_1 池が最大で，N_2, N_3 池のそれぞれ約 20～30 倍，8～45 倍，8～19 倍を示した。また *Br. plicatilis* の耐久卵の形成量は N_1 池のみに顕著で，N_2, N_3 池においては殆んど認められなかつた。従つて養殖池は水草の密生した天然池に比べて，動物プランクトンの生産量は甲殻類，輪虫類，繊毛虫類のいずれも著しく大きく，特に輪虫類の生産が顕著で，かつその耐久卵の形成量も大きい。

溶存酸素の垂直分布の日週変化: N_1 池においては成層は明瞭ではなく，終日上下層ほぼ同じであるが，時間的変動は大きい。水草の密生帯（N_2 池）では垂直的成層が発達，表層（0～25 cm）では N_1 池と類似した日週変化を示すが，それ以深の底層では含有量は少なく，かつ時間的変動も小さい。これは水草の密生が深層への光の透入を妨害し，また池水の擾動を制限しているためと考える。

補償深度: N_1 池における植物プランクトンの補償深度は約 68 cm にあり，これは透明度の約 2.5 倍に相当する。N_3 池における植物プランクトンならびに水生植物 *Potamogeton pectinatus* の補償深度はほぼ等しく，約 40 cm にある。N_3 池の池水は透明に近く，透明度は 100 cm 以上であるのにも拘らず，透明度 27 cm の N_1 池よりも浅いところに補償深度があるのは，密生した *Potamogeton pectinatus* の葉が水中への入射光を制限しているためと考える。また水草の呼吸作用による酸素消費は植物プランクトンに比して著しく大きいことが分つた。

水変り: N_1 池では 7 月中旬と 8 月上旬に 2 回の水変りがおこり，養殖魚の斃死，鼻上げが観測された。この水変りにはいずれも汽水産輪虫 *Brachionus plicatilis* の大増殖が伴なつた。しかし N_2, N_3 の天然池には水変りは全く認められなかつた。

VI. 考　　察

1. 水変りの程度の決定機構について

養鰻池における水変りが，放養量ならびに給餌量の少ない粗放的養魚期には軽微であつたのに，放養量と給餌量が増した現在の集約的養魚期において大量の養殖魚の斃死を伴なつた大規模の水変りがおこるようになつた[1]。この原因とその機構はどのように説明したらよいか。この水変りの程度の歴史的変化は，現在においては，給餌養鰻池と少量給餌ならびに無給餌の粗放的養魚池との水質，プランクトン，水変りの程度などの観測結果の比

較によつて推定できるであろう。

本研究の結果によると，給餌養鰻池（N_1 池）は天然池（N_2, N_3 池）に比べて，池水中の N, P, Fe などの含有量は常に大きく，藍藻，緑藻などの micron-algae の現存量は大きく，また動物プランクトン（甲殼類，輪虫類，織毛虫類）の現存量も大きく，輪虫類の大増殖が見られ，かつひどい水変りが見られ，養殖魚の斃死，鼻上げが見られている。また透明度は小さく，溶存酸素の季節的，時間的変動も大きい。これに対し粗放的養魚池（N_2, N_3 池）においては水変りは全く見られていない。養殖池と天然池との間に，このような水変りの程度の差を生じた原因と機構は下記の因果連鎖系によつて説明できよう。

集　約　養　魚　（放養量・給餌量の増加）
↓
栄養塩類の増加　（水中への回帰量の増加）
↓
植物プランクトン量の増加　（藍藻・緑藻の micron-algae の増加）
↓
動物プランクトン量の増加　（甲殼類・輪虫類・繊毛虫類）
（特に輪虫の増殖量と増殖速度の増大）
↓
水変りの程度の増大　（水変りの変化量と速度の増大）
↓
養殖魚の被害の増大

この外に，養殖池における水変り時の被害の増大には，摂餌によるナウギの酸素欠乏に対する抵抗性の減退，植物プランクトン密度の過大による溶存酸素量の日週変化における下限の低下，有毒物質の生成量と生成速度なども関与していると考えられる。

大量の養殖魚の斃死を伴なつた大規模の水変りが集約的養魚期におこるようになつた原因と機構も上掲の因果連鎖系によつて充分説明できる。この考えはさらに養鰻池における施肥と水変りとの関係[2]，ならびに輪虫の培養実験などの実験的研究[3)4)5)]によつても裏付けられる。

2.　汽水養魚池における大型水生植物のプランクトン生産に対する影響について

湖沼，溜池，養魚池における高等水生植物の魚類ならびにプランクトンの生産に対する影響については多くの報告がある。大型水生植物の繁茂が余りに大きいと，これが水中の栄養塩類を吸収し，プランクトンの生産を妨げ[7)8)9)10)11)]，魚類の棲息およびその取揚作業を妨害し[12]，また魚類の生産は小さい[7]。

Hasler and Jones ('49)[13] によると，大型水生植物のプランクトン生産に及ぼす影響を実験的に追究した結果，水草を植えた池は，植えない池に比べて，植物プランクトン量ならびに輪虫量は明らかに小さい。しかし甲殻類は両池に有意な差はなく，また魚の成長度は変動が大きく水草の影響は明瞭でなかつたことを報告し，大型水生植物は植物プランクトンならびに輪虫類の増殖に悪影響を与え，両者間に拮抗作用の存在を認めている。本研究における *Potamogeton pectinatus* の密生した天然池（N_2, N_3 池）は，水草を欠く給餌養鰻池（N_1 池）に比べて，植物プランクトンならびに輪虫類の生産は明らかに小さいので，この点は Hasler and Jones の結果とよく一致する。しかしこの関係は甲殻類の生産にも認められるので，この点は彼らの結果と異なつている。従つて汽水養魚池においても大型水生植物とプランクトンの生産の間には拮抗作用が認められ，投餌の有無がこの作用をさらに強化しているといえよう。この拮抗作用は大型水生植物が水中の栄養塩を

吸収し，その葉が水面近くに拡がり水中への入射光を妨害しているために，植物プランクトンの増殖が小さく，それに依存する動物プランクトンの生産も小さいと説明できよう。

Potamogeton pectinatus（リュウノヒゲモ）は，伊勢湾西岸の汽水池に最もよく生育する水生植物であり，特に天然池に卓越している。養鰻池においては，春季に植物プランクトンの増殖が悪く，池水が長期にわたつて澄んでいるときには必らず生育しはじめ，一度生育がはじまると，施肥によつても制圧は困難になり，養魚成績は著しく減退する[10]。この水草の分布，生態，ならびに養鰻池に対する影響の実態，養殖魚の成長に及ぼす影響などに関しては不明な点が多く，今後さらに追究すべき多くの興味深い問題を含んでいる。

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輪虫の海水培養と保存について

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On the Culture of Mixohaline Rotifer *Brachionus plicatilis* O. F. MÜLLER in the Sea Water

(*With 11 Text-figures and 15 Tables*)

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Résumé

As the artificial rearing of the highly economical marine animals has been attended widely in Japan, the cultivation of the forage organisms has become an urgent problem for it. The marine rotifer is now demanded and expected much as food for the larval cultures of fish, lobsters and crabs. For the purpose of meeting the demand, the author has tried successfully the cultivation of the mixohaline rotifer *Brachionus plicatilis* O. F. MÜLLER in the sea water.

1) Selection and isolation of the culture species

Br. plicatilis for this study was collected from the eel-culture ponds (Cl 2–3‰) in Tsu City, Mie Prefecture, Middle Japan. For the isolation of *Br. plicatilis* from the freshwater rotifer, the method of salinity selection was adopted. (Table 2 and Fig. 2)

2) Culture medium and food

For the culture medium and food of *Br. plicatilis*, the green water, with marine green alga, *Chlamydomonas* sp., *Dunariella* sp. and *Chlorella* sp. cultured in the sea water and the diluted sea water of various salinity, was used.

3) Culture method

Br. plicatilis for the sea water culture was got by several subculturings of the amictic females collected from a mixohaline eel-culture pond (Cl 2.1‰), in the green water of high salinity (Tables 3–6). The effect of the salinity upon the growth of *Br. plicatilis* cultured in the sea water, as shown in Figs. 4 and 5, is that the speed of the growth rises higher as the salinity lessens. Scarce growth of the rotifer was observed with the salinity more than Cl 19‰ (Fig. 6). In the case of the medium whose salinity gradually raised by the evaporation, the rotifer can grow in the very dense sea water of Cl 54‰.

4) Tolerancy against the change of salinity

The tolerancy of *Br. plicatilis* in the case of being immediately transferred from the green weter of the salinities, Cl 10, 12, 14, 16 and 18.2‰, into the diluted sea water of various salinities (Cl 10–18.2‰), is as shown Table 9. And its survival rate in 24 hours is nearly 100%.

5) Effect of food supply

For the food of *Br. plicatilis*, the living cells of marine alga, *Chlamydonas* sp. and *Dunariella* sp., are most suitable (Figs. 7 and 8). The effect of food suplly on the growth of the rotifer varies with the phase in the course of its growth. The supply at the early time of the highest reproductive potentiality is the most

effective, while the supply at the time of its disappearance is the least effective, but in the case, the survival rate is the highest (Fig. 9).

6) Light condition

The growth and survival rate of *Br. plicatilis* are remarkably higher under the continuous illumination in 2 k lux, than in the darkness. On the other hand, the quantity of the formed dormant eggs and that of the existing male are much greater in the darkness (Fig. 10).

7) Temperature condition

Br. plicatilis belongs to the warm-water species, and first appears to be observed in May (W.T. 17–20°C) in the eel-culture ponds in Mie Pref., comes to its peak in midsummer, but shows gradual decrease in November, and disappears completely in the first decade of December when the water temperature goes down below 10°C. In case of the laboratory culture, it is possible in the room temperature, from June to October, but in the winter time, the oven is required for the culture.

8) On the dormant eggs of *Br. plicatilis*

Br. plicatilis, either in the natural population in the eel-culture ponds or in the laboratory, never fails to form much quantity of the dormant eggs at its growth period; its dormant eggs are so heavy as to sink to the bottom (Tables 7, 8 and 10; Figs. 7 and 11). The latent period of the dormant eggs is from 7 to 12 days at the least. The infiuences of the high salinities (Cl 10–18‰) on the hatchability of the dormant eggs of *Br. plicatilis* which are formed in the green water of each salinity (Cl 0.5–18‰) are as shown in Tables 11–13. In case of the medium of high salinity, the hatchability of the dormant eggs rises higher to the salinity of the medium in which they are formed. The influence of the high salinity on the hatchability of the dormant eggs in the dry mud gathered from the two eel-culture ponds (Cl 2.96 and 6.61‰) is as shown in Tables 14 and 15. In either case, they can be hatched when the salinity is Cl 15‰ and lower, but cannot be when the salinity rises to Cl 17‰ and higher. The dormant eggs of *Br. plicatilis* are extremely strong in their persistency against drying, and it can preserve itself no more than 12 months in natural drying.

I. はじめに

輪虫類は孵化直後の稚魚の最初の餌料として，重要な役割を果していることは，ワカサギ[1]，アユ[2)3)]等の淡水魚において明かにされている。また最近，海産魚介類の人工飼育試験が盛んになるに及び，各種の餌料微生物の培養が重要な問題となつて来た。稚魚，クルマエビ，イセエビ，ガザミ等の幼生餌育の動物性餌料としては，現在主として brine shrimp の nauplius，フジツボの nauplius，繊毛虫等の生餌が使用されているが[4)5)6)7)8)]，大きさ 100～200 μ，水中に懸游し且つ運動が緩慢で，簡単に海水培養の出来る海産輪虫が餌料として期待され要望されている[8)]。しかし従来，海産輪虫の培養に成功した例を知らない。

著者は本邦汽水に広く分布し，特に養鰻池に大増殖し，水変りの有力な原因になる汽水産輪虫，*Brachionus plicatilis* Müller（シオミズツボワムシ）の増殖生理並に増殖機構を明かにするために，数年来その培養実験を行つて来た。これらの実験結果に基き，Cl 2‰の養鰻池産のシオミズツボワムシを海水で培養することに成功した。大量培養方式の確立には，更に開発すべき種々の問題が残されているが，現在までに得られた結果をとりまとめて報告したい。

II. 培　養　法

1. 培養種の選択

培養種としては汽水産輪虫，*Brachionus plicatilis* Müller（シオミズツボワムシ）を用いた。本種の分布は普遍的で，汽水のみでなく，食塩を含んだ内陸鹹湖にも棲息する。本邦では現在までに，北海道，中部，近畿，中国の汽水域並に沿海に分布するのが知られている[9,10,11,12,13]。その他の地方の汽水域にもおそらく分布するものと考える。シオミズツボワムシは温水性種に属し，三重県の養鰻池群では，5,6月頃の水温 17〜20°C 以上から出現し，夏季に最も卓越し，11月頃から減少しはじめ，水温10°C以下になる12月上旬には全く消滅する[14,15]。本種を多量に採集するには，夏季に Cl 2‰以上の汽水養鰻池でプランクトンネットによつて集めるのが最も簡単である。Cl 5‰以上の養鰻池では殆んど *Brachionus plicatilis* の単一種より成るが，それ以下の塩分の池では，*Br. calyciflorus*, *Br. quadridentatus*, *Br. urceolaris*, *Br. angularis* 等の淡水産輪虫類と混在する。これらの淡水産輪虫は Cl 5‰以上の塩分では培養出来ない。形態的にはこれらは *Br. plicatilis* に類似しているので，*Br. plicatilis* を正しく同定することが大切である。*Br. plicatilis* は後頭棘を6本有する点で，特に *Br. quadridentatus*, *Br. urceolaris* に酷似する。しかし *Br. plicatilis* は腹甲前縁が4葉に分れているので，前2種と容易に識別出来る[16]。

培養の種苗としては，処女生殖雌虫（♀♀, amictic female）と耐久卵（冬卵，休眠卵）の両方を用いることが出来る。前者は汽水池からプランクトンネットで採集するか，耐久卵を孵化させて用い，後者は本種が多数棲息した養鰻池の底泥を風乾して用いる。

Table 1. The isolation of the rotifers from the plankton crustacea in pond water of eel-culture pond.
Chlorinity of pond water 3.02‰. W.T. 22.5-20.9°C.

Zooplankton	Time in day			
	0	1	2	3
Copepoda				
Pseudodiaptomus inopinus	14	0	0	0
Paracyclopina nana	4	0	0	0
Nauplius (Copepoda)	25	0	0	0
Cladocera				
Moina dubia	11	tr.	0	0
Rotifera				
Brachionus plicatilis	3266	1458	1169	113
Br. calyciflorus	158	37	1	0
Br. quadridentatus	250	160	152	6
Br. angularis	49	39	27	2
Br. urceolaris	39	34	8	0.4
Hexarthra fennica	16	tr.	0	0
Filinia breviseta	4	tr.	0	0
Total nos. of rotifer /cc	3782	1728	1357	121
Survival rate (%)	100	46	36	3

2. 種苗の分離

Br. plicatilis の amictic female を培養の種苗とする場合には，塩分濃度の大きい養鰻池の水変り中には，プランクトンは本種の単一種より成る場合があるので，これを利用出来る。しかし一般には，*Br. plicatilis* は *Br. calyciflorus*, *Br. quadridentatus*, *Br. urceolaris*, *Br. angularis*, *Filinia breviseta* 等の淡水産輪虫のみでなく，プランクトン甲殻類の *Sinocalanus tenellus*, *Pseudodiaptomus inopinus*, *Paracyclopina nana*, *Moina dubia* 等と混在するのが普通である。従つて培養に先立つて，*Br. plicatilis* をこれらの動物プランクトンから分離する必要がある。

a. プランクトン甲殻類からの輪虫類の分離

輪虫類の増殖した養鰻池からプランクトンネットで採集した動物プランクトンを，小型容器（約500cc）に濃縮し，放置すると，間もなく *Sinocalanus*, *Pseudodiaptomus* 等の甲殻類は死滅し，ついで *Moina* 等は1日後には殆んど完全に斃死し，輪虫類のみが生き残る。輪虫類は上液と共に他の容器に移す。この方法によつて輪虫類を甲殻類から大量に

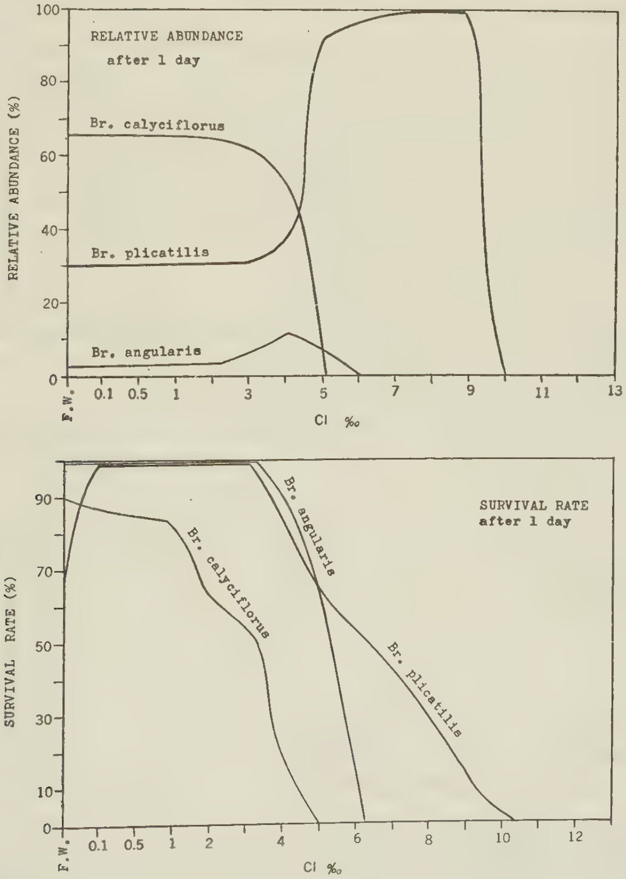


Fig. 1. The effect of salinity change upon the survival rate of rotifers collected from an eel-culture pond (Cl 2.68‰) in Tsu City, Mie Prefecture.

F.W. freshwater; Cl 0.1-13‰, diluted sea water.

分離出来る。(Table 1)

容器中の輪虫の組成は2日後までは殆んど同じであるが，3日後からは *Br. calyciflorus* が著しく減少し，*Br. plicatilis* の割合が大きくなる。輪虫類の歩止りは2日後までは相当に大きいが，3日後には約3%程度である。従つて甲殻類からの輪虫類の分離は1日後，7〜8月の高温時には数時間後で充分である。

b.　汽水産輪虫 *Br. plicatilis* の淡水産輪虫類からの分離

プランクトン甲殻類から分離した輪虫の混合材料から汽水産輪虫 *Br. plicatilis* を分離するには，次の2つの方法がある。

i)　致死塩分濃度の差を利用する方法

津市北部のM_3池（Cl 2.68‰）から採集し，プランクトン甲殻類から分離した輪虫類の混合材料（輪虫類の組成と密度：*Br. plicatilis* : *Br. calyciflorus* : *Br. angularis* : *Br. urceolaris*=212 : 596 : 18 : 12 個体/cc, 25.3 : 17.1 : 2.1 : 1.5(%)）を，淡水から Cl 13‰ の稀釈海水に亘る16種の塩分濃度に多数個体を直接に移した場合の輪虫の組成変化と生残率は Fig. 1 に示した。

淡水産輪虫類の *Br. calyciflorus*, *Br. quadridentatus*, *Br. urceolaris*, *Br. angularis* 等は1日後には，Cl 5〜6‰ 以上の塩分では，殆んど死滅し，汽水産の *Br. plicatilis* のみが生き残る。しかし本種も Cl 10‰以上では全滅する。従つて Cl 5〜9‰の稀釈海水に，前述のようにして，甲殻類から分離した輪虫の混合材料を直接に投入することによつて，淡水産を淘汰し，*Br. plicatilis* のみを分離することが出来る。この方法による *Br. plicatilis* の生残率は塩分濃度が大きくなる程小さくなるので，Cl 5〜6‰の稀釈海水による淘汰が歩留りもよく能率的である。(Table 2)

Table 2. The isolation of a mixohaline rotifer *Brachionus plicatilis* from fresh-water rotifers by the transplantation of the rotifers of eel-culture pond (Cl 3.02‰) to diluted sea water (Cl 5‰).
W.T. 23-21°C.

Rotifera	Time in day			
	0	1	2	3
Brachionus plicatilis	840	359	189	59
Br. calyciflorus	26	0	0	0
Br. quadridentatus	106	9	0	0
Br. angularis	22	0	0	0
Br. urceolaris	16	0	0	0
Total numbers /cc	1010	368	189	59
Survival rate (%)	100	43	23	7

ii)　増殖塩分濃度の差を利用する方法

淡水産輪虫類との混合材料から，汽水産の *Br. plicatilis* の単一種苗を得る他の方法は，増殖塩分濃度の差を利用する方法である。この方法は，前述の塩分淘汰法に比べて，*Br. plicatilis* の密度が小さいとき，その上手間のかからない点で便利である。また海水培養の種苗を得るのにそのまま利用出来る。

Fig. 2 は津市北部のM_3池 (Cl 2.86‰) から採集し，プランクトン甲殻類を除いた，次のような組成と密度の輪虫の混合材料

Species	Density nos./cc
Br. plicatilis	1540
Br. calyciflorus	930
Br. quadridentatus	25
Br. angularis	70
Br. urceolaris	40
計	2605

を原種として，稀釈海水 Cl 5, 6, 7, 8‰ に予め培養しておいた海産緑藻の *Chlamydomonas* sp. の green water (夫々 1.41, 1.50, 1.84, 1.81×10⁶ cells/cc) を，200 cc 容量のコルベンに各 200cc とり，各コルベンに輪虫を 10 個体/cc の割合に種付し，恒温槽 (25°C, 暗黒) に保つた場合の輪虫の増殖状況を示した。

1 日後には，*Br. calyciflorus*, *Br. urceolaris*, *Br. quadridentatus*, *Br. angularis*,

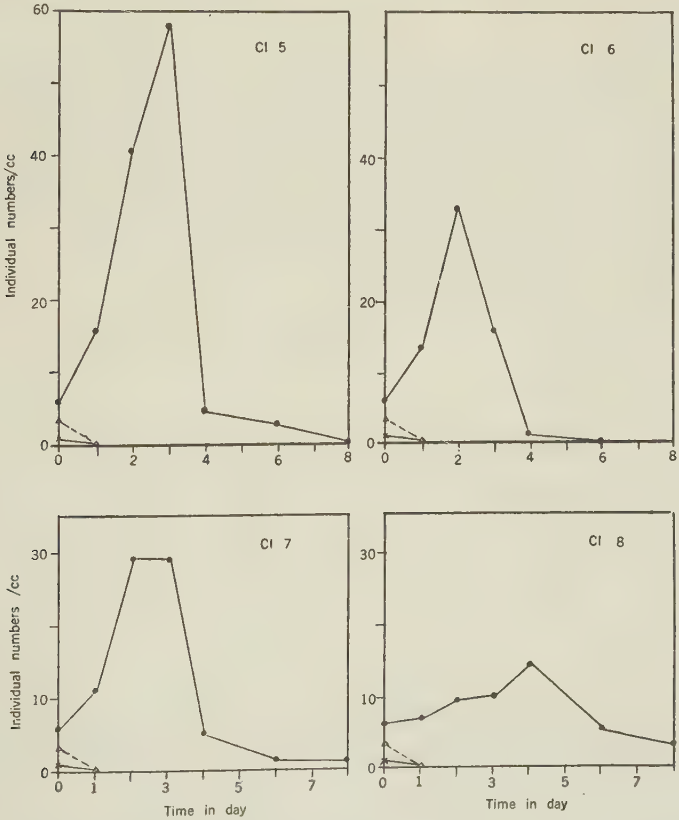


Fig. 2. The effects of higher salinities (Cl 5-8‰) upon the growth of rotifers collected from an eel-culture pond (Cl 2.86‰) in Tsu City Mie Prefecture.

Food source: marine green algae, *Chlamydomonas* sp., 1.41-1.84×10⁶ cells/ml. In thermostat (25°C, dark).

-●-●- *Br. plicatilis*; --△--△-- *Br. calyciflorus*

-×-×- *Br. angularis*

等の淡水産輪虫は殆んど消滅し増殖は認められなかつた。これに対し，*Br. plicatilis* のみは顕著に増殖し，2〜3日後に最大密度に達し，夫々 58, 33, 29, 14 個体/cc を示した。餌料としての *Chlamydomonas* の量には大差がないので，輪虫の最大密度の差は塩分の影響と考える。

従つて，*Br. plicatilis* が淡水産輪虫と混在している場合，本種の種苗を多量に得る方法としては，Cl 5〜7‰の稀釈海水に micron-algae を培養しておき，この green water に前述の輪虫混合体を種付し，*Br. plicatilis* のみを増殖させ，分離し，最大密度時の amictic female を種苗として用いるのが最も簡便である。著者は多くこの方法によつて種苗を分離している。またこの方法によつて，輪虫の寄生繊毛虫をも control することが出来る。

Br. plicatilis の培養源としては，amictic female の他に，耐久卵を用いる。耐久卵は室内の培養個体群においても簡単に得られ，また養鰻池底泥中には多量の本種の耐久卵を含んでいるので[18]，底泥を風乾して用いる。耐久卵の形成，孵化，保存については後述する。

3. 培養液並に餌料

Br. plicatilis の海水培養の餌料として，現在使用しているのは，すべて海産緑藻で，*Chlamydomonas* sp. (長径 9〜12 μ, 短径 7〜9 μ), *Dunariella* sp (直径 4〜12 μ), *Chlorella* sp. (直径 2〜5 μ) の3種である。第1の種はアメリカ産で，本学水産学部辻井禎博士から分与されたもので，第2は，山口県内海水産試験場前川兼佑場長から種苗を分与された。第3は，当研究室において，三重県沿岸海水から分離培養した。

これらの海産緑藻の培養液は次の通りである。

A液:	KNO_3	20.2 g
	D.W.	100 cc
B液:	$MgSO_4$	4 g
	$CaCl_2$	4
	$Fe(NH_4)(SO_4)_2$	1
	HCl (conc)	2 cc
	D.W.	100 cc
C液:	KH_2PO_4	1.53 g
	D.W.	100 cc

培養海水は予め，湯煎あるいは蒸気によつて完全に滅菌し，完全に冷えてから，その 1 *l* に，これも別に殺菌した A 液の 0.55 cc 並に B 液の 0.50 cc を加え，次に C 液の 0.50 cc を加える。その後，前記の藻類を接種し，20 W 2 本の昼光色蛍光灯で側面から連続照射する。*Chlamydomonas* 並に *Dunariella* は海水産であるのにも拘らず，塩分に対する耐忍性が極めて強く，前者は Cl 5‰までの汽水でも海水と同様によく増殖し，後者は，Cl 2‰まで極めてよく増殖する。

このようにして培養した緑藻の green water を *Br. plicatilis* の培養液並に餌料としている。

4. 海水培養の輪虫種苗の作り方

汽水産輪虫 *Brachionus plicatilis* Müller の海水培養の困難点は，汽水性養鰻池産の

amictic female を Cl 10‰ 以上の汽水並に海水に直接に移すと斃死し，また汽水で形成された耐久卵も海水では孵化増殖し難いことである。しかし，汽水産の amictic female は，subculture を高塩分の方に徐々に移していくと，数回の subculture で，Cl 2.1‰ の養鰻池産の本種も，Cl 18‰の海水でも培養出来るようになる。その方法について稍々詳細に述べたい。

第1次培養

輪虫の材料：　津市北部の養鰻池（K_2池，Cl 2.1‰）から昭和34年6月1日に採集した *Br. plicatilis* を原種とした。

培養液と餌料：　Cl 3.5, 5.5, 7.5, 9.5, 11.5, 13.6‰の稀釈海水に海産緑藻 *Chlamydomonas* sp. を培養した green water を使用した。

方法：　30 cc 容量の試験管に上記塩分の各 green water を 20 cc とり，前記の輪虫を約1000個体宛種付し，容器は南側窓辺においた。水温は 22～23.9°C。結果は Table 3 に示した。

Table 3.　1st culture
The reproduction of the mixohaline rotifer *Br. plicatilis* transplanted directly from the pond water of the eel-culture pond (Cl 2.1‰) into the green water*) of various salinities (Cl 3.5–13.6‰).
*) with marine green algae, *Chlamydomonas* sp.　W.T. 22–24°C.

Cl ‰ subcultured	Time in day						
	1	2	3	4	5	7	11
3.5	++	++	+++	+++	+++	+	±
5.5	++	++	+++	+++	+++	+	±
7.9	+	+	+	++	++	+++	++
9.5	±	±	±	+	+	++	++
11.5	−	−	−	−	−	±	±
13.6	−	−	−	−	−	−	−

Cl 13.6‰に移したものは，1日後に全部斃死，Cl 11.5‰では1日後には殆んど消滅したように見えたが，7～11日には極く僅かに殖えた。Cl 9.5‰では最初は相当に斃死するが，3日後から稍々増殖する。Cl 7.5‰では最初の斃死も小さく，4日後から顕著に増殖する。Cl 3.5～5.5‰では全く影響を受けず，著しく増殖する。

第2次培養

第1次培養において Cl 7.5, 9.5‰の green water に増殖した *Br. plicatilis* を第2次培養の種苗とした。

培養液並に餌料：　Cl 9.7, 11.8, 13.8, 15.8, 18.0, 19.0‰に培養した *Chlamydomonas* の green water を用い，各 50 cc を 100 cc 容量のコルベンにとり，輪虫は夫々 1.8 個体/cc, 2.8 個体/cc の割合に種付し，恒温槽（28°C，暗黒）に保つた。実験期間は6月15～20日。結果は Table 4 に示した。

Cl 7.5‰並に Cl 9.5‰で培養した *Br. plicatilis* を原種とした場合，その後の増殖状況は Table 4 に明かのように，略々一致する。即ち Cl 9.7～11.8‰ではよく増殖するが，Cl 13.8～15.8‰では僅かに増殖するに過ぎない。Cl 18‰では殆んぱ増殖せず，Cl 19‰

Table 4. 2nd subculture
The influence of high salinity (Cl 9.7-19‰) upon the growth of *Br. plicatilis* culturd in both diluted sea water of Cl 7.5‰ and 9.5‰.
The figures indicate the numbers of rotifer per cc.
W.T. 28°C, thermostat (darkness).

Cl ‰ subcultured	Initial chlorinity ‰							
	Cl 7.5‰				Cl 9.5‰			
	Time in day				Time in day			
	0	2	4	5	0	2	4	5
9.7	1.8	8.5	53.0	84.0	2.8	9.5	56.0	88.5
11.8	1.8	9.0	29.5	34.0	2.8	5.0	28.5	33.5
13.8	1.8	3.5	11.0	14.0	2.8	1.5	6.5	6.5
15.8	1.8	0.5	8.0	13.0	2.8	1.5	10.0	3.5
18.0	—	—	—	—	2.8	1.0	4.5	2.0
19.0	—	—	—	—	2.8	0	0	0

では2日後には全く消滅した。従つて第2次培養によつて，Cl 11.8‰までは極めて顕著に，Cl 15.8‰までは稍々よく増殖するようになる。

第3次培養

第2次培養における Cl 11.8‰の green water に増殖した *Br. plicatilis* を第3次培養の種苗とした。

培養液並に餌料: Cl 14, 16, 18, 19‰ の *Chlamydonas* sp. の green water 50 cc を 200cc 容量のコルベンにとり，上述の *Br. plicatilis* を種付けし，恒温槽 (28°C, 暗黒) に保つた。実験期間6月20日～25日。結果は Table 5 に示した。Cl 19‰では 2 日後には殆んど消滅したが，Cl 14～18‰ では増殖が認められた。全体的に増殖量の小さいのは餌料としての藻量が少いためと考える。

Table 5. 3rd subculture
The influence of high salinity (Cl 14-19‰) upon the growth of *Br. plicatilis* cultured in the diluted sea water of Cl 11.8‰.
The figures show the numbers of rotifer per cc.
W.T. 28°C, thermostat (darkness).

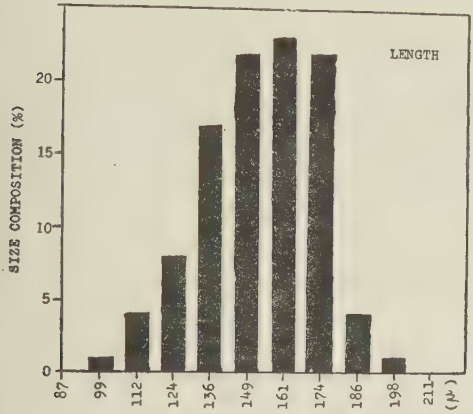
Cl ‰ subcultured	Time in day			
	0	2	4	5
14	tr.	7.5	10.0	5.0
16	tr.	6.5	16.0	6.5
18	tr.	7.5	5.5	8.5
19	tr.	0	0	0

第4次培養

第3次培養において，Cl 16 並に 18‰の green water に増殖した6日後の *Br. plicatilis* を種苗とし，夫々 Cl 16 並に 18‰の *Chlamydomonas* の新鮮な green

water に subculture し，20W 昼光色蛍光灯で側面から連続的に照射した。実験期間 6 月26日～7 月11日。結果は Table 6 に示した。

増殖速度は稍々おそくなる傾向があるが，Cl 16, Cl 18‰ でも明瞭な増殖が認められる。



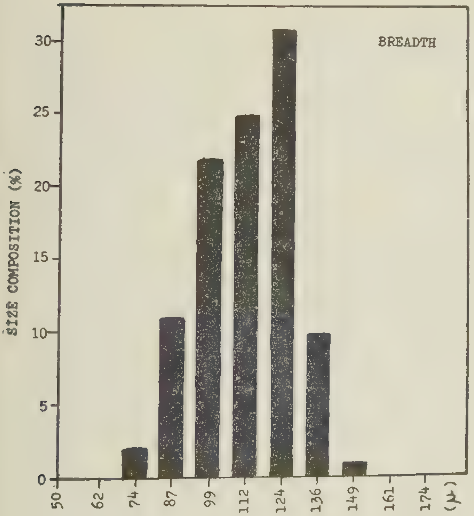


Fig. 3. The size composition of *Brachionus plicatilis* O. F. Müller cultured in sea water (Cl 18‰) with the marine green algae, *Chlamydomonas* sp.

Table 6. 4th subculture
The effect of high salinity (Cl 16 and 18‰) upon the growth of *Br. plicatilis* cultured in both green water of Cl 16‰ and 18‰.
Date: VI 26-VII 11, 1959. W.T. room temperature.
The figures show the numbers of rotifer per cc.

Cl ‰ subcultured	Time in day			
	4	7	11	15
16	3	22	123	40
18	0.3	0.3	6	36

要するに，*Br. plicatilis* の高塩分に対する適応性は極めて強く，Cl 2.1‰ の養鰻池産の本種は，直接に移した場合には，Cl 10‰以上では 1 日後には全滅するのにも拘らず，高塩分の green water に徐々に subculture を続けていくと，約 1 カ月，4 回の subculture で，Cl 18‰ の海水でも充分培養出来るようになつた。このようにして Cl 18‰ で培養した *Br. plicatilis* は 8 月の盛夏にも，室温で，時々新鮮な *Chlamydomonas* の green water で subculture することによつて，培養は維持され，9 月 10 日には 225個体/cc にも達した。Cl 18‰ で培養した *Br. plicatilis* の体長組成は Fig. 3 の通りである。

	被甲長 (μ)	被甲幅 (μ)
♀♀	99～198	74～149
♂	87～ 99	50～ 62
D♀	161	124
耐久卵	87	62

III. 海水培養型の増殖に対する各種要因の影響

1. 増殖に対する低塩分の影響（蛍光灯連続照射の場合）

輪虫の材料: 海産緑藻を培養した Cl 18.2‰の green water を用いて実験室で飼育した *Br. plicatilis* を本実験の種苗とした。

培養液並に餌料: Cl 5, 7, 9, 11, 13, 15, 16‰の稀釈海水に *Chlamydomonas* sp. を培養した7種の塩分濃度の green water を使用した。

方法: 各種塩分の green water 各々 70 cc を 100 cc 容量の大型試験管にとつた。輪虫種付前の藻量は次の通りであつた。

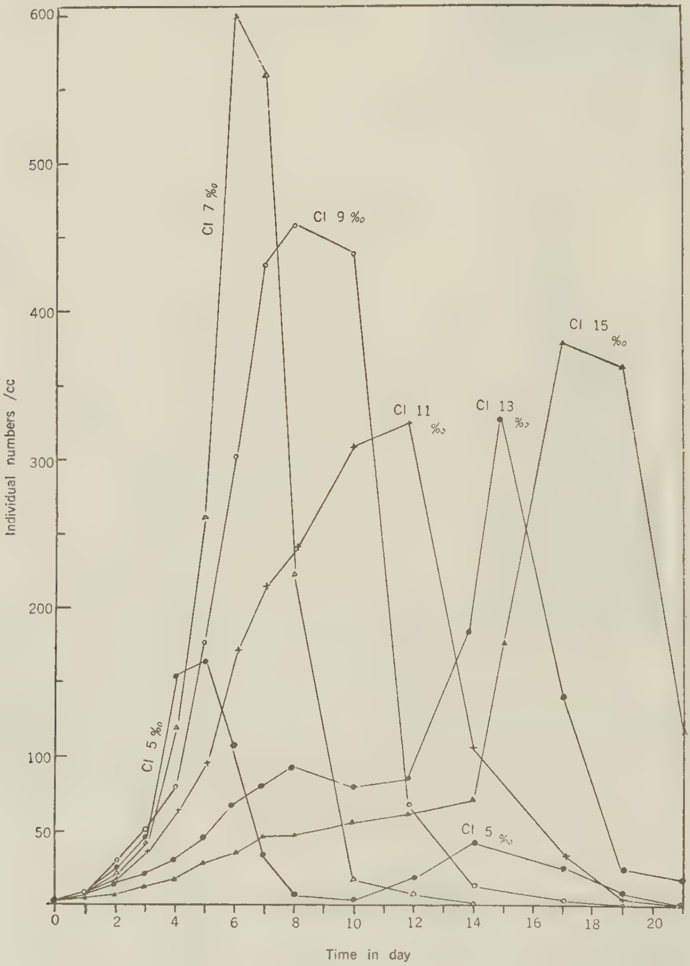


Fig. 4. The effects of lower salinities (Cl 5–15‰) upon the growth of *Br. plicatilis* cultured in the sea water (Cl 18‰).

Continuous illumination (2k lux); Food source: marine *Chlamydomonas*, 1.20–2.90×10^6 cells/ml. W. T. 24.8–28.5°c.

Chlorinity ‰	Cell numbers/cc
5	1.54×10^6
7	1.20
8	1.54
11	1.94
13	1.40
15	2.90

各試験管に前記輪虫をいづれも 3 個体/cc の割合に種付けし，室内の培養棚に並べ，側面から20W昼光色螢光灯で連続的に照射した。W.T. 24.8～28.5°C。結果は Fig. 4 に示した。

第 1 に，増殖速度は塩分の小さい程大きく，最大密度期は次のようになり，

Cl ‰	最大密度時
5	4～5 日後
7	6～7
9	8～9
11	10～12
13	15～16
15	17～19

特に Cl 13, 15‰では増殖速度は他に比して，著しく遅滞する傾向がある。

第 2 に，飽和密度の高さは，餌料としての *Chlamydomonas* 量が同一でなく，且つその後の増殖程度が明かでないので，比較は困難である。しかし Cl 5‰では増殖量は他に比べて著しく小さく，最大は Cl 7‰で最大密度 605 個体/cc，次いで Cl 9‰で，Cl 11‰以上は稍々劣る。

第 3 に，♂の最大密度，耐久卵の形成量は Table 7 に示した。♂の最大密度並に耐久卵の形成量は Cl 7.3‰，9.3‰が大きく，それから高塩分あるいは低塩分になると，小さくなる。耐久卵の形成率並に♀の最大密度にも同様の傾向が見られる。

従つて，Cl 18‰で約 3 ケ月培養した *Br. plicatilis* の塩分に対する抵抗性は充分に固定しているのではなくて，本種の本来の棲息域，即ち汽水の Cl 7～9‰において，増殖速度，増殖量，♂並に D♀の出現量等は最も大きい。

Table 7. The influence of low salinity (Cl 5.3–15.1‰) upon the production of dormant eggs of *Br. plicatilis* cultured in the sea water (Cl 18‰).— Under continuous illumination.

Condition		Maximum density of ♀	Dormant eggs formed	Dormant eggs formed	Maximum density of ♂
Cl ‰	Initial food cells /cc	nos. /cc	nos. /cc	%	nos. /cc
15.1	2.90×10^6	381	7.42	1.9	12
13.1	1.40	326	6.44	1.9	16
11.2	1.94	321	28.89	9.0	31
9.3	1.54	457	53.51	11.7	50
7.3	1.20	605	60.19	9.9	81
5.3	0.77	164	0.83	0.5	7

2. 増殖に対する低塩分の影響（暗黒の場合）

前実験において，海水培養型輪虫を，*Chlamydomonas* の各種塩分の green water に移した場合，その後の *Br. plicatilis* の増殖は，Cl 7, 9‰で最もよく，Cl 11‰以上では増殖速度は小さくなる結果が得られた。この原因が塩分によるのか，或いは蛍光灯の連続照射のために，餌料としての *Chlamydomonas* の輪虫種付後の増殖量の相違，水質の違いに起因するかは明かでない。この点を究明するために，最初の藻量を同一にし，その後の増殖をおさえ，且つ水温を一定にするために，恒温槽(暗黒)を使用して追試を行つた。

輪虫の材料: Cl 18‰の green water 中に形成された耐久卵を，Cl 18.2‰ の *Chlorella* の green water で孵化増殖させた *Br. plicatilis* を使用した。

培養液並に餌料: Cl 18.2‰の海水を蒸溜水で稀釈して，Cl 18.2, 16, 14, 12, 10‰を作り，それに，別に培養した *Chlamydomonas* を遠沈し，各培養液に略々同量の *Chlamydomonas* (0.98×10^6 cells/cc) を再懸濁させ，培養液並に餌料とした。各塩分の green water は 200 cc 容量のコルベンに 100 cc 宛とり，輪虫を 1.3 個体/cc の割合に種付し，恒温槽(30°C，暗黒)に保つた。実験結果は Fig. 5 に示した。

結果の大体の傾向は，前実験と同じく，輪虫の増殖速度並に増殖量は塩分の小さい程大

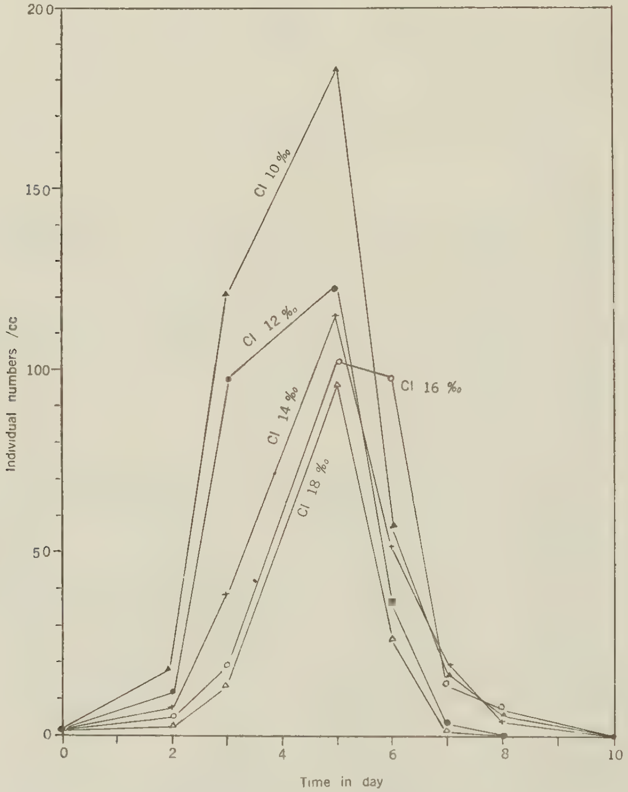


Fig. 5. The effect of lower salinities (Cl 10–18‰) upon the growth of *Br. plicatilis* cultured in the sea water (Cl 18.2‰). Food source: marine *Chlamydomonas*, 0.98×10^6 cells/ml.

きい。しかしその差は前実験程顕著ではない。また耐久卵の形成量並に形成率も，塩分の小さい程大きい。しかし♂の最大密度と塩分との間には，前実験程はつきりした関係は見られない(Table 8)。前実験に比し，暗黒に保つた場合には，種付前の藻量の少いのも1因と考えられるが，輪虫の増殖量は♀，♂いづれにおいても小さい。

Table 8. The influence of low salinity (Cl 10–18.2‰) upon the production of dormant eggs of *Br. plicatilis* cultured in the sea water (Cl 18‰).—In the darkness.

Condition		Maximum density of ♀ nos. /cc	Dormant eggs produced nos. /cc	Dormant eggs produced %	Maximum density of ♂ nos. /cc
Cl ‰	Initial food cells /cc				
18.2	0.98×10⁶	96	0.10	0.10	3.0
16	〃	102	0.41	0.40	6.5
14	〃	115	0.55	0.48	3.0
12	〃	122	0.88	0.72	4.5
10	〃	183	0.79	0.43	5.5

この2つの実験から，海水培養型の *Br. plicatilis* は海水より塩分の小さい，Cl 7～10‰位の汽水において，増殖速度，増殖量，並に耐久卵の形成量も大きいといえよう。更に長期に亘つて海水で培養を継続した場合，この特性がどのように変化するかを追跡することは興味深い問題であるが，これらは将来の問題である。

3. 増殖に対する高塩分の影響

輪虫の材料: Cl 18.2‰ のgreen water で培養中の *Br. plicatilis* を種苗とした。

培養液並に餌料: Cl 18.2‰ の海水で培養中の海産緑藻 *Chlorella* の容器の栓をとり，自然蒸発によつて Cl 20.8‰, 19.8‰, 19.4‰, 並に Cl 20.8‰ の green water を蒸溜水による塩分濃度を 1/2 に稀釈したもの，4種の green water を培養液並に餌料とした。各液中の藻量は最初， 夫々 14×10⁶, 7×10⁶, 4×10⁶, 7×10⁶ cells/cc であつた。各種塩分濃度の green water を 200cc 容量のコルベンに各々 100 cc とり，更に各々輪虫を 1.3個体/cc の割合に種付し，恒

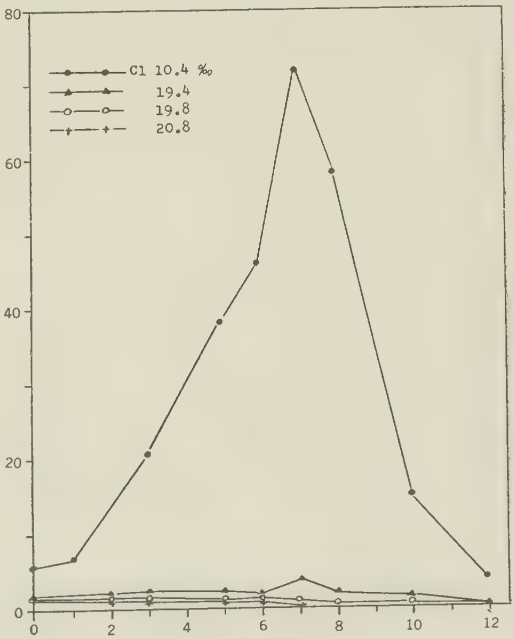


Fig. 6. The effect of higher salinities (Cl 19.4–20.8‰) upon the growth of *Br. plicatilis* cultured in the sea water (Cl 18.2‰).
Food source: marine *Chlorella*.
In thermostat (30°C, dark).

温槽 (30°C, 暗黒) に保つた。結果は Fig. 6 に示した。

Cl 20.8, 19.8, 19.4‰ の green water では餌料は充分存在するのにも拘らず，増殖は全く見られず，Cl 20.8‰では7日後に，Cl 19.8, 19.4‰では12日後に全滅した。♂，D♀の出現も見られず，従つて耐久卵の形成も認められなかつた。しかし Cl 10.4‰ では普通の増殖が見られ，♂は6～7日後に出現，D♀は7～8日後に出現し，耐久卵の形成も認められた。

従つて Cl 19‰以上においては，*Br. plicatilis* の海水培養型の増殖は極めて阻害されるといえよう。

4. 高鹹水に対する耐忍性

海水培養の *Br. plicatilis* は，Cl 19‰以上の塩分では，その増殖が著しく阻害される

Table 9. The tolerancy of *Br. plicatilis* in the case of being alternatively transferred from the green water of various salinities (Cl 10-18.2‰) into the diluted sea water of the same salinity (Cl 10-18.2‰).
The marks, ++～−, indicate the degree of survival, ++ 100%; + 50%; ± 10-30%; ∓ 10%; − dead (100%).

Initial Cl ‰	Cl ‰ transplanted	Time in hour					
		2	4	6	24	48	72
10	10	++	++	++	++	+	±
	12	++	++	++	++	+	∓
	14	++	++	++	++	±	∓
	16	++	++	++	++	±	∓
	18.2	++	++	++	+	±	−
12	10	++	++	++	++	+	∓
	12	++	++	++	++	+	∓
	14	++	++	++	++	±	−
	16	++	++	++	++	±	−
	18.2	++	++	++	+	∓	−
14	10	++	++	++	++	+	−
	12	++	++	++	++	+	−
	14	++	++	++	++	+	−
	16	++	++	++	++	+	−
	18.2	++	++	++	++	+	−
16	10	++	++	++	++	±	−
	12	++	++	++	++	±	−
	14	++	++	++	++	±	−
	16	++	++	++	++	±	∓
	18.2	++	++	++	++	±	±
18.2	10	++	++	++	++	±	±
	12	++	++	++	++	±	±
	14	++	++	++	++	+	±
	16	++	++	++	++	+	±
	18.2	++	++	++	++	+	±

ことは前実験の結果明かになつた。しかし徐々の高鹹化に対してどのような抵抗性をもつているかを明かにするために，この簡単な実験を行つた。

輪虫の材料: 三重県楠町の S_2 池(昭和34年12月1日採泥)の風乾泥中の耐久卵から Cl 10‰の稀釈海水で孵化した *Br. plicatilis* を種苗に使用した。

培養液並に餌料: Cl 10‰の稀釈海水に *Chlamydomonas* sp. (海産緑藻) の green water 1 *l* を 1 *l* 容量のビーカーにとり，前記輪虫を種付けし恒温槽 (28°C) に入れ，硝窓の外側から 20W 昼光色螢光灯で随時照射した。実験開始: 昭和34年12月26日。

蒸発によつて培養液の塩分は濃縮され，60日後の2月25日には，Cl 54.2‰の高鹹となつていた。しかし *Br. plicatilis* はこの高塩分にも拘らず，35 個体/cc の割合に生残し，且つ amictic egg を有する個体も存在し，増殖の可能性も認められた。この塩分中の♀♀の被甲長は 149～161 μ，被甲幅 99～118 μを示し，器底には耐久卵が沈積し，その長径は 87～99 μ，短径 59～62 μ であつた。

更に3月5日には，培養液の Cl は約70‰となつたが，このときには *Br. plicatilis* は全部斃死した。この高塩分においても海産緑藻の *Chlamydomonas* は緑色を呈し，生存した。

従つてこの簡単な実験結果から，*Br. plicatilis* は徐々の高鹹化に対しては，驚くべき抵抗性を有していることが分る。本種が内陸鹹湖に広く棲息出来ることも首肯される。またこの特性は，本種の大量海水培養（自然蒸発による高鹹化が絶えずつきまとう）にとつて有利な点であろう。

5. 各種塩分 (Cl 10, 12, 14, 16, 18.2‰) **で培養した *Br. plicatilis* の塩分変化に対する抵抗性**

輪虫の材料: Cl 10, 12, 14, 16, 18.2‰の各塩分で培養した *Chlamydomonas* の green water を培養液並に餌料として，恒温槽 (29°C，暗黒) 中で増殖させ，最大密度に達した (4日後) *Br. plicatilis* を実験に供した。

方法: Cl 18.2‰の海水と蒸溜水により，Cl 10, 12, 14, 16, 18.2‰の塩分濃度を作り，各々 30 cc 容量の試験管に 20 cc 宛とり，これらは恒温槽に入れ，輪虫の培養液の水温と同じにした。増殖した輪虫は夫々小型ビーカーに移し，No. 16 の絵絹を張つた広口ピペットを用いて，静かに液のみを吸いとり，輪虫を濃縮し，各塩分濃度の試験管に約 300 個体の輪虫を移し，その後の生残，運動状況を 72 時間後まで観察した。結果は Table 9 に示した。Cl 10‰並に Cl 12‰ の低鹹から Cl 16, 18‰ の高鹹に移した場合，輪虫は最初の1～2時間は，いづれも表層に集り，逆に高鹹 (Cl 18, 16‰) から低鹹に移したものは，最初器底近くに集つた。他のものは液中に全体に分散した。しかし 4～6 時間後からは全体的には表層に集合する傾向が見られた。

24 時間後には，10→18‰並に 12→18‰では，1 部斃死したが，他のものでは殆んど 100‰生存した。48 時間後には生残は著しく小さくなり，72 時間後には大部分が斃死し，極く 1 部が生残つた。

従つて，Cl 10～18‰で培養した *Br. plicatilis* を，餌料を含まない Cl 10～18‰の塩分に相互に，直接に移しても，24 時間以内の生残率は殆んど 100%であるが，48～72 時間後の生残は著しく悪くなる。このことから，*Br. plicatitis* を水産動物の餌料として用いる場合には，24時間以内に食い潰される程度にやることが，水質保全の点から好ましい。ま

た輪虫の増殖速度と増殖量の大きい Cl 10～12‰位の green water で, *Br. plicatilis* を培養し，これを水産動物の幼生飼育槽（普通は塩分は Cl 10～12‰より大きい）に餌として補給する方式が最も能率的であるといえよう。

6. 増殖に対する餌料としての植物プランクトンの影響

輪虫の海水培養の餌料として，現在海産緑藻の *Chlamydomonas* sp., *Chlorella* sp., *Dunariella* sp. の3種を用いている。輪虫の増殖に対するこれらの植物プランクトンの餌料効果の比較は，輪虫種付後の藻類の増殖，生理状態，大きさ等の差異という困難な問題があり，仲々容易ではない。ここでは大体の傾向を把えることを目的として実験を行つた。

i) *Chlamydomonas* と *Chlorella*

輪虫の材料: Cl 16.4‰の *Chlamydomonas* の green water で培養中の *Br. plicatilis* を濃縮して種苗とした。

方法: 海産緑藻の *Chlamydomonas* sp. と *Chlorella* sp. とを Cl 10‰の稀釈海水を

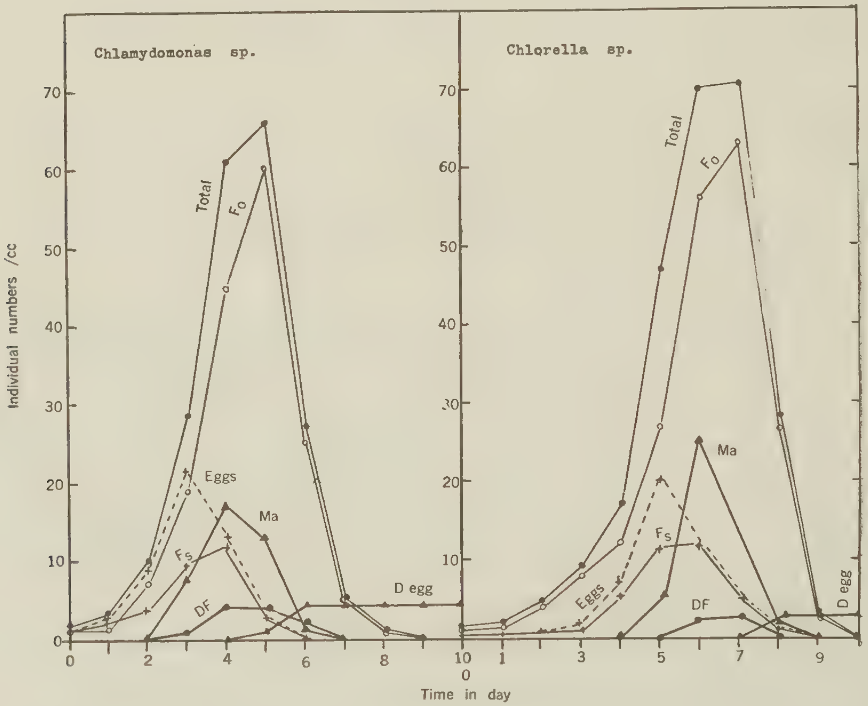


Fig. 7. The effect of two marine green alga, *Chlamydomonas* sp. and *Chlorella* sp., upon the growth of *Br. plicatilis*.

Cl 10‰ diluted sea water; In thermostat (25° C, continuous illumination). F_0: female without eggs; Eggs: amictic and male eggs; F_s: female with amictic and male eggs; DF: female with dormant eggs; D-eggs: dormant eggs produced; M_a: male; Total: F_0+F_s+DF.

用いて，同一方法によつて培養し，培養液並に餌料とした。green water の各 100 cc を 200 cc 容量のコルベンにとり，上記輪虫を 1.6 個体/cc の割合に種付けし，恒温槽 (25°C) に入れ，硝子窓を通して，20W 昼光色蛍光灯で上側方から連続照射した。結果は Fig. 7 に示した。*Chlamydomonas* を餌料とした場合が，*Chlorella* の場合より，増殖速度は稍々大きく，♂並にD♀の出現も早い。従つて増殖曲線の位相は，前者の場合が後者より 2 日位早い。しかし全体的の増殖機構もまた飽和密度の高さも両者に著しい差はない。耐久卵の形成量は，前者では 439/100 cc，後者では 128/100 cc で，*Chlamydomonas* を餌とした場合が大きい。

ii) *Dunariella* sp.

培養液並に餌料： Cl 2, 4, 6, 8, 10 ‰ の稀釈海水に，山口県内海水試から分与された，海産緑藻 *Dunariella* sp. を培養し，各塩分の green water を *Br. plicatilis* の培養液並に餌料とした。細胞数は $2.0 \sim 2.5 \times 10^6$ cells/cc で大差はない。

輪虫の材料： 昭和35年5月23日に，津市北部の水変り中の K_6 池 (W.T. 24.6°C, Cl 2.0‰) から採集した *Br. plicatilis* を種苗とした。

方法： 200 cc 容量のコルベンに，上記の各種塩分の green water を 100 cc 宛とり，輪虫を 6.6 個体/cc の割合に直接に加え，昼光色蛍光灯 (20W) で側面から連続照射した。結果は Fig. 8 に示した。

Cl 10‰では，*Br. plicatilis* は 2 日後には斃死した。Cl 8‰では，最初は死滅したかに見えたが，5 日後から急激に増殖をはじめた。Cl 2, 6‰では正常の増殖曲線を示し，最大密度は，いづれも 7 日後に見られ，夫々 392 個体/cc，436 個体/cc に達した。これらの 4 つの green water における餌料としての藻量は，Table 10 に示したように，大差はないので，増殖曲線の

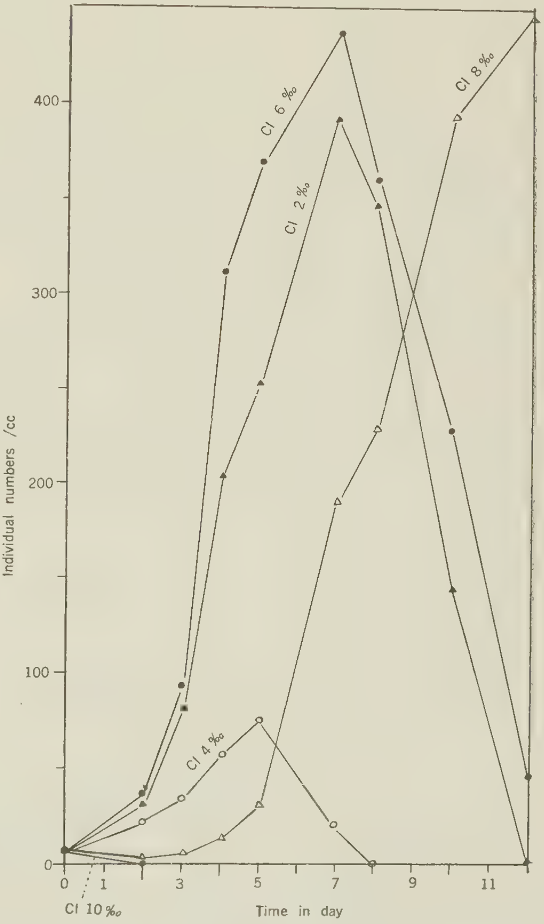


Fig. 8. The effect of the marine green algae, *Dunariella* sp. upon the growth of *Br. plicatilis* collected from an eel-culture pond (Cl 2.0‰) in Tsu City, Mie Prefecture.
Continuous illumination (2 k lux).
W.T. 24.6-27.5°C.
Density of algae, $2.0 \sim 2.5 \times 10^6$ cells/cc.

差は塩分に依存することは明かである。しかし Cl 4‰での増殖は悪い。この原因は明かでない。amictic female の著しい増殖とは逆に，この場合の耐久卵の形成量は，22～19/100 cc 程度で，極めて小さく，且つ♂の最大密度も 1～4/cc 程度で小さい。

Table 10. The effect of the marine green algae, *Dunariella* sp. upon the production of dormant eggs of *Br. plicatilis.*

Condition		Maximum density of ♀ nos. /cc	Dormant eggs produced nos. /cc	Dormant eggs produced %	maximum density of ♂ nos. /cc
Cl ‰	Initial food cells /cc				
2	2.2×10⁶	392	0.22	0.06	1.0
6	2.0	436	0.19	0.04	4.0
8	2.1	445	—	—	—
10	2.5	0	0	0	0

以上の2つの実験結果から，*Br. plicatilis* の海水培養の餌料としては，上記の海産緑藻，*Chlamydomonas*, *Dunariella*, *Chlorella* 等が利用出来る。特に前2種が培養の簡単であること，並に高い密度になり得る点から見て好適であろう。*Br. plicatilis* の増殖に対する他の植物プランクトンの影響については，伊藤(未発表)[17]を参照されたい。

7. 増殖に対する餌料補給の影響

餌料を補給しない場合の *Br. plicatilis* の増殖曲線は，前にもいくつかの例を挙げたように，ロジスチッン曲線におけるような，長い飽和期はなく，飽和密度に達してからは，急激に斃死する[15]。このような増殖過程のいろいろな時期に，餌料補給をした場合，増殖曲線はどのように変化するか。♂の出現，耐久卵の形成はどのような影響を受けるか。等を明かにすることは，この輪虫の増殖機構の解明にも，また実際的には培養の維持についての知見を得るにも重要な問題である。この点を明かにするために，汽水について本実験を行つた。

輪虫の材料：1959年6月11日に，津市北部の K_2 池 (Cl 2.70‰) の水変り中に大増殖した *Br. plicatilis* を種苗に用いた。

培養液並に餌料：Cl 3‰の稀釈海水に培養した海産緑藻の *Chlamydomonas* の green water を基礎培養液並に餌料とした。藻量は 0.41×10^6 cells/cc である。200 cc 容量のコルベンに 100 cc を用いた。

方法：上述の基礎培養液並に餌料の5個のコルベンに，*Br. plicatilis* を各々 7.3 個体/cc の割合に種付けし，培養期間中，餌料としての *Chlamydomonas* の増殖をおさえるために，恒温槽(28°C，暗黒)に保つた。餌料補給は1日後，3日後，5日後，1·3·5日後の4群に分けて行い，補給しないのを control とした。補給方法としては，Cl 5‰に培養中の *Chlamydomonas* を遠沈させ，それを培養液中に再懸濁させた。補給量は，1日後，3日後，5日後のものは夫々 0.54×10^6 cells/cc の割合に，1·3·5日後の3回補給は，夫々 0.27×10^6 cells，計 0.81×10^6 cells/cc の割合に加えた。従つて全餌量は，control は 0.41×10^6，1日後，3日後，5日後のものはいづれも 0.95×10^6，1·3·5日後のものは 1.22×10^6 cells/cc である。

結果：Fig. 9 に示した。

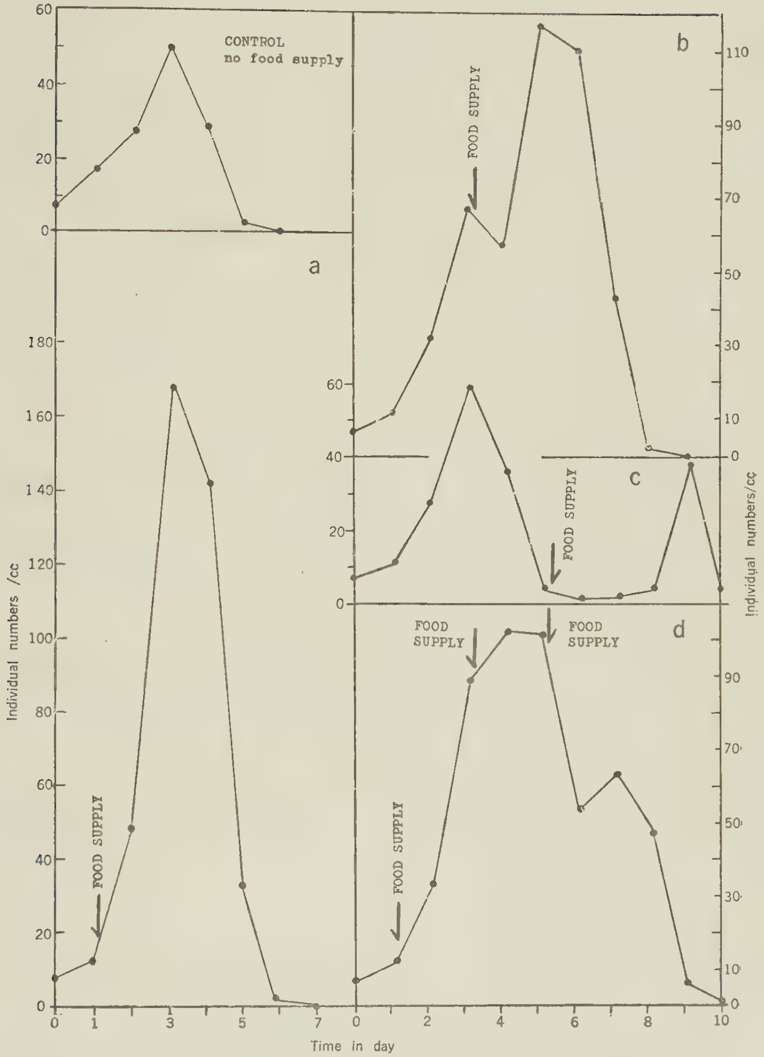


Fig. 9. The effect of food supply upon the growth of *Br. plicatilis*.
Basic food: marine *Chlamydomonas*, 0.4×10⁶ cells/ml.
Food supply: marine *Chlamydomonas* centrifuged, 0.54×10⁶ cells/ml in a, b and c; 0.27×10⁶ cells/ml in d.
Cl 3‰ diluted sea water; in thermostat (28°C, dark).

餌料補給を行はないもの (control) では，輪虫の増殖速度並に増殖量も小さい。最大密度は3日後に 50 個体/cc で，6日後には全く消滅した。♂並にD♀の出現量も小さく，耐久卵の形成量は 29/100 cc，形成率は 0.59%である。

1日後に餌料補給したものでは，増殖に対する餌料補給の効果は最も顕著で，増殖速度並に増殖量は著しく増大する。しかし最大密度は，補給しないものと同じく，3日後に見られ，169 個体/cc に達したが，6日後には全く消滅した。♂の出現も最大で，52 個体/cc に達したが，D♀の出現量は割合に小さく，耐久卵の形成量は 52/100 cc，形成率は 0.36

%である。

3日後に餌料補給したものでは，増殖曲線には2つの山が見られた。3日後は，餌料補給をしないものに明かのように，輪虫の基礎餌料による最大密度時に相当する。3日後の餌料補給の1日後には♀の密度は却つて減少しているが，しかし amictic egg をもつた，♀数並に卵数は増加し，第2の増殖の先駆が認められ，5〜6日後に最大密度 118 個体/cc に達し，その後 control に2日程おくれて8日後に消滅した。♂並にD♀の出現には著しい効果は認められないが，しかし耐久卵の形成量は 159/100 cc で他に比べて大きい。

5日後に餌料補給したもの一この補給時は， control に明かのように， 最大密度を過ぎ，消滅寸前に相当する。餌料補給の効果は直ぐには表はれないで，3〜4 日の latent period が存在し，4日後に第2の山（38 個体/cc）に達したが，継続せず，直ぐに斃死が続いた。♂並にD♀の出現には全く効果は認められず，耐久卵の形成量は，25/100 cc，形成率は 0.42%で，control と大差はない。

1·3·5日後の3回に補給したもの一第1日後の補給の効果は，前述の場合と同じく，著しい。第3日後の補給の効果は見るべきものはない。第5日後の補給の効果は速効的でなく，その2日後に稍々増殖したが，その後は急激に減少して，10 日後には殆んど消滅した。耐久卵の形成量は 173/100 cc，形成率は 1.69%，♂の最大密度は 24 個体/cc，これらの値は1日後のみに補給のした場合のそれによく一致する。

以上の結果を要約すると，次のようにまとめることが出来る。

1) 餌料補給の効果は，輪虫の増殖過程における補給時期によつて，著しく異り，増殖ポテンシヤルの最も大きいと考えられる種付 1 日後の補給が最も効果的である。輪虫の最大密度時（3日後）がこれに次ぎ，消滅期（5日後）の餌料補給の効果が最も小さく，且つ遅効的であり，2〜3日後に効果が表はれる。

2) ♂並にD♀の出現に対する餌料効果も，その時期によつて異り，1日後の補給が最も効果的で，3日後の補給の効果も稍々認められるが，5日後の補給には効果は認められない。

3) しかし，amictic female の生残密度に対する餌料補給の効果は，補給時期のおそいのが効果が大きい。

4) 従つて，amictic female の増殖速度と増殖量を大きくし，且つ耐久卵の形成量を多くするには，最初の餌料密度を大きくするか，餌料補給は輪虫の増殖初期に行うのが効果的である。しかし培養を長く維持するためには，輪虫の増殖末期の補給が効果的であるといえよう。

8. 光　条　件

輪虫の増殖に対する光の影響は，餌料としての藻類の光合成による溶存酸素，pH 並に餌料そのものの増加等の間接的影響が，直接的作用に卓越していると考えられる。暗黒と光の連続照明との場合の，餌料としての藻類の密度，培養液の pH，輪虫の増殖状況等の相異を明かにするために，汽水について実験を行つた。

輪虫の材料: 1959年6月17日に，津市北部の K_3池（Cl 3.2‰，pH 7）の水変り中の，*Br. plicatilis* を種苗とした。

培養液並に餌料: Cl 3‰の稀釈海水を基礎培養液として，海産緑藻 *Chlamydomonas* sp. を増殖させた green water を用いた。

方法: 150 cc 容量の大型試験管に，Cl 3‰の稀釈海水を 80 cc とり，それに *Chlamydomonas* を接種し，20W 2 本の昼光色蛍光灯で側面から連続的に照明し，6 日間培養し green water を得た。その後，第 1 試験管はそのままにし，control とした。第 2 並に第 3 試験管には夫々輪虫を 6.8 個体/cc の割合に加え，第 2 は同様に引続いて照明し，第 3 は暗箱に保ち，第 1・第 2 の横においた。*Chlamydomonas* の細胞数の変化，培養液の pH (ガラス電極 pH 計使用)，輪虫の増殖，♂並にD♀の出現，耐久卵の形成量等を追究した。

結果: Fig. 10 に示した。

1) 輪虫　欠，連続照明・・・対照区； 2) 輪虫　加，連続照明・・・照明区；

3) 輪虫　加，暗　　黒・・・暗黒区

第 1・第 2・第 3 試験管を便宜上，夫々，対照区，照明区，暗黒区と略記する。

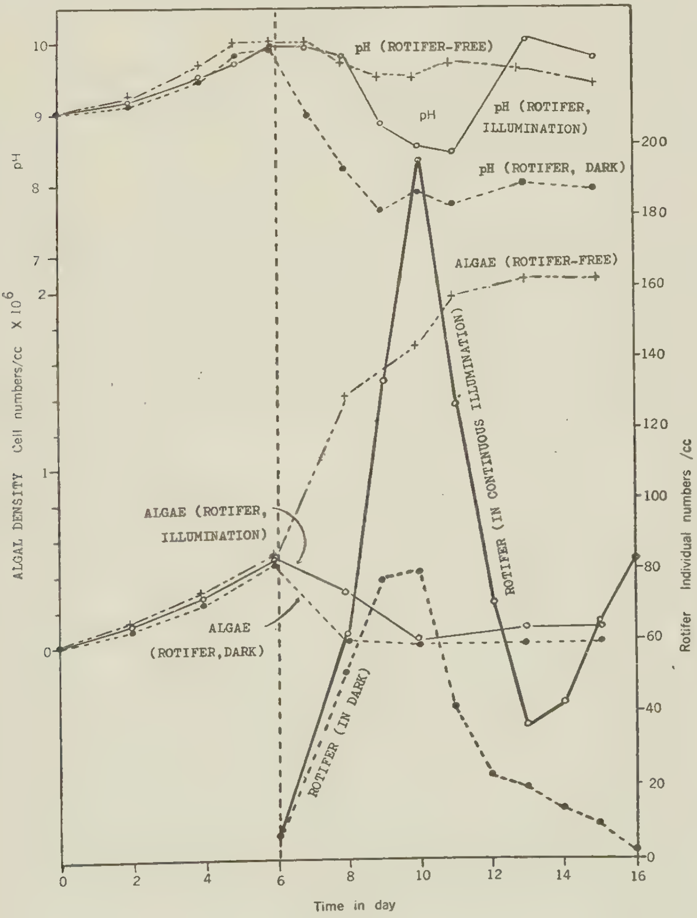


Fig. 10. The effects of continuous illmination (2 k lux) and darkness upon the growth of *Br. plicatilis*.
Medium: Cl 3‰ diluted sea water. Food. marine *Chlamydomonas*.

a)　*Chlamydomonas* の細胞数

どの試験管でも，6 日後までは殆んど同じ速度で増殖し，細胞数は 6 日目には，夫々 49.8, 48.4, 42.2×10⁴ cells/cc に達した。その後対照区では，*Chlamydomonas* は急激に増殖し，13～15日後には，206×10⁴ cells/cc を示した。しかし照明区と暗黒区では，輪虫の増殖につれて，細胞数は急激に減少し，輪虫接種の 4 日後には微量になつた。*Chlamydomonas* の減少速度は暗黒区の方が大きい。照明区では，光によつて藻類が増殖したためと考える。また照明区では，13日後から，その他に，*Chaetoceros*, *Amphora* 等の硅藻が著しく増殖し，培養液は緑褐色に変つた。暗黒区ではこの現象は見られなかつた。

b)　培養液の pH

最初の pH はいづれも，9.0 であつたが，藻類の増殖に伴つて上昇し，6日後には 9.9～10 を示した。輪虫接種後，暗黒区では急に低下し，9 日後には最低 7.6 を示した。照明区では輪虫を接種しても，最初の 2 日位は殆んど低下しないが，その後急激に低下し，11日後に最低 8.4 を示した。しかし輪虫が斃死し，硅藻が増殖して，pH は再び上昇し，pH＝10を示した。従つて照明区が暗黒区より常に培養液の pH は高い。

c)　輪虫の増殖

輪虫の増殖速度は，照明区が暗黒区より大きく，また飽和密度の高さも，前者は後者の約 2.5 倍である。しかし飽和密度の時期には差はない。

照明区では，輪虫は接種 4 日後に最大密度 197 個体/cc に達し，5 日後から急激に斃死しはじめ，7 日後には 37 個体/cc に減少した。しかしこの場合は，8 日後から再び増殖がはじまつた。これは *Chlamydomonas*, *Amphora*, *Chaetoceros* の増殖と一致しているので，餌料増加に原因すると見做される。この期間中の耐久卵の形成量は 0.91/cc，形成率は 0.46%，♂の最大密度は 2.5 個体/cc であつた。

暗黒区では輪虫の増殖速度はおそく，4 日後に最大密度 80 個体/cc に達し，その後急減し，10日後には殆んど消滅した。耐久卵の形成量は却つて大きく，2.97/cc，形成率は 3.71%，♂の最大密度は 4.0 個体/cc を示した。

要約:

20W 2 本の昼光色蛍光灯の連続照明，暗黒のいづれの場合も，*Br. plicatilis* は増殖する。しかし増殖速度と増殖量は照明区が著しく大きく，且つ歩留りも大きい。これは照明によつて餌料藻類が増殖し，前項で述べた餌料補給の役割を果していることと，光合成による溶存酸素量の多いことに起因すると考えられる。この場合，培養液の pH も照明区の方が高いが，伊藤(未発表)[17] の結果から見ると，これが増殖に顕著な影響を与えるとは考えられない。しかし耐久卵の形成量並に形成率，♂の出現量は，逆に暗黒区の方が大きい。

従つて *Br. plicatilis* の培養において，増殖量を大きくし，培養を維持するには連続照明を行う方が効果的である。耐久卵の形成量，♂の出現量は，前述の例にも明かのように，照明区の方が大きい場合もあり，結果は不規則であり，有性生殖に対する光の影響については更に検討が必要である。輪虫の増殖と光の強さとの関係は実験していないが，餌料の培養には 20W 2 本の蛍光灯照明が効果的であるが，輪虫の接種後は 20W に減光するのが輪虫の増殖には適当ではないかと考えている。

9.　温度条件

Br. plicatilis は温水性種に属し，津附近の養鰻池群においては，5 月上・中旬 (W.T.

17〜20°C）から大増殖をはじめ，夏から秋にかけて最も卓越し，11月から減少しはじめ，水温が10°C以下になる12月上・中旬には池水から全く消滅する。それ以後から4月に亘つては耐久卵で池底に休眠する。*Br. plicatilis* の増殖速度は，水温と密接な関係があり，自然個体群，実験個体群のいづれにおいても，水温の高い程，増殖速度は大きい[15]。海水培養型の増殖と水温との関係については，未だ詳細な実験は行つていない。しかし前述の多くの実験結果を総合すると，その関係は，汽水の場合と同様に考えてよい。6〜10月には特別の保温の必要はなく，室温で充分培養出来る。8月の盛夏には35°Cに達した場合もあつたが，抵抗性が大きく，殆んど影響されなかつた。しかし冬期の培養には保温が必要である。恒温槽を用いると冬期でも容易に培養を維持出来る。

IV. 耐久卵の形成，孵化，保存について

Br. plicatilis は養鰻池の自然個体群においては，多輪廻性に属し，5〜11月に度々有性生殖を行い，耐久卵が容易に形成され，夥しい耐久卵が池底に沈積している[14][18]。また室内の培養個体群においても，耐久卵は普通に形成され，器底に沈積する[19]。この耐久卵は乾燥，温度，その他の化学的悪条件に対する抵抗性が極めて強い[20]。耐久卵は本輪虫の培養の種苗となり，また大量の耐久卵は，brine shrimp と同様にその孵化個体そのものを水産動物の餌料に利用出来よう。本研究においては，海水培養の基礎問題の一環とし若干の実験を行つた。

1. 耐久卵の形成

Fig. 11 は，Cl 18.2‰の green water で培養中の *Br. plicatilis* を種苗として，Cl 9‰の *Chlamydomonas* を培養した green water を培養液並に餌料とし，輪虫を3個体/cc の割合に種付した場合の，*Br. plicatilis* の♂並にD♀の出現，耐久卵の形成時期を，この輪虫の増殖過程と共に示したものである。

増殖に先駆して，amictic egg を持つた♀♀が急激に増加し，amictic egg 数は更に増し，いづれも5〜6日後に最大となる。その後両者は急激に減少し，12〜15日後には0になる。これらとは逆に，卵を持たない♀が急速に増加し，その最大密度は，9〜10日後に見られる。これも10日後から急激に斃死する。

♂は2日後から出現しはじめるが，最大密度は7〜8日後に見られ，その後次第に斃死し，12日後には全滅する。D♀（耐久卵を持つた♀）は♂の出現に2〜3日おくれて出現し，最大密度は♂に同じく，7〜8日後に見られる。従つて♂並にD♀の出現時に mictic female（♂♀）が出現したことは確実であり，雄卵は♂の最大密度の2日前頃に最大が見られる。amictic female と mictic female の識別は困難であり，また amictic egg と male egg との区別は初期には明瞭であるが，後には明かでなくなるので，この場合には分けてない。

Br. plicatilis のD♀は *Br. calyciflorus*, *Br. quadridentatus*, *Br. urceolaris*, *Br. angularis* 等と異り，耐久卵を母被甲内に有する。D♀は体の比重が大きいためか，器底近くに多い。D♀はやがて斃死し，耐久卵は母被甲に入つたまま，あるいは遊離し，器底に沈積する。D♀は12〜14日後には全部斃死し，水中には耐久卵と生き残つた1部の amictic female のみが存在する。D♀の有する耐久卵は普通1個で，極く稀に2個の場合もある。

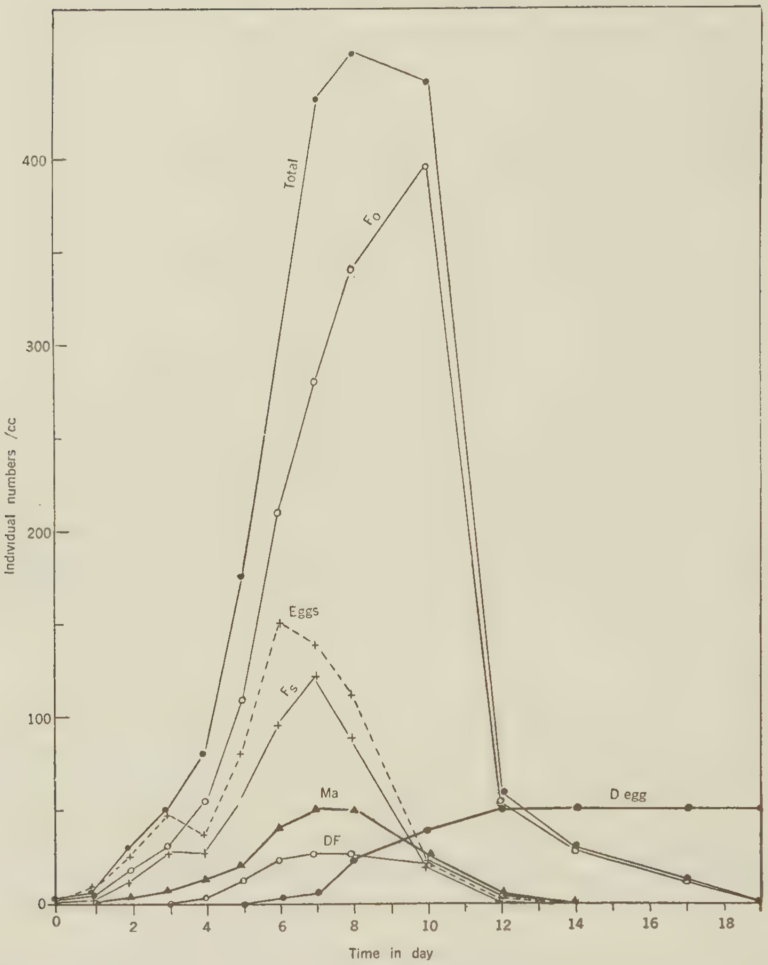


Fig. 11. The reproduction pattern of the mixohaline rotifer, *Brachionus plicatilis* O.F. MÜLLER.

Culture condition: Cl 9‰ diluted sea water. Food: marine *Chlamydomonas*, Continuous illumination (2 k lux); W.T. 24.8–27.5°C.

F_0: female without eggs; Eggs: amictic and male eggs; F_s: female with amictic and male eggs; DF: female with dormant eggs; D-egg: dormant eggs produced; M_a: male; Total: F_0+F_s+DF.

耐久卵の形成量は一回の培養で，最大 60/cc を示す場合もあるが，1/cc 以下の場合もあり，変動が大きい。全体的に見ると，形成量は培養条件（培養液，餌料の質，量，その他）が好適で，増殖の大きいときに大きいといえる。この変動要因並に耐久卵の形成の好適条件の解明は今後の重要な問題の一つである。

2.　耐久卵の孵化増殖

輪虫の耐久卵は，形成されてから孵化までに，数週間から数カ月の latent period を必要とするといはれているが，*Br. plicatilis* の耐久卵の “眠り期間” は，形成されてから，7～12 日位である。しかしこの場合の孵化率は小さい[17]。これに対し晩秋に形成され，

越冬した耐久卵の孵化率は著しく大きく，100%に近い[20]。耐久卵の眠りに対する乾燥，塩分との関係については伊藤（未発表）[17]を参照されたい。低温，溶存酸素，NH_4-Nの影響については明かにしていない。

Br. plicatilis の耐久卵の孵化過程，孵化に対する 2，3 の要因については既に発表した[20]。ここでは，耐久卵を海水培養の種苗として使用する場合の基礎として行つた実験結

Table 11. The effect of salinity change upon the hatchability of the dormant eggs of *Br. plicatilis* produced under various salinities (Cl 9, 7, 5, 3, 1, 0.5‰).
The marks, ＋＋＋＋～－, indicate the numbers of rotifer hatched out, ＋＋＋＋ >300; ＋＋＋ 100-300; ＋＋ 50-100; ＋ 10-50; ± 1-10; － none.
W.T. 23-29°C.
Media: green water (*Chlamydomonas* sp.) of Cl 10, 12, 14, 16, 18‰.

Dormant eggs	Cl ‰ trans-planted	Time in day						
		1	2	3	4	5	6	7
D_9	10	－	－	±	±	±	±	±
	12	－	－	±	±	±	±	±
	14	－	－	－	－	－	－	－
	16	－	－	－	－	－	－	－
	18	－	－	－	－	－	－	－
D_7	10	－	±	＋	＋	＋＋	＋＋＋	＋＋＋
	12	－	－	±	±	±	±	±
	14	－	－	±	±	±	±	±
	16	－	－	－	－	－	－	－
	18	－	－	－	－	－	－	－
D_5	10	±	±	＋	＋＋	＋＋＋	＋＋＋	＋＋＋＋
	12	±	±	＋	＋	＋＋	＋＋	＋＋
	14	±	±	±	＋	＋	＋	＋
	16	－	－	±	±	±	±	±
	18	－	－	－	－	－	－	－
D_3	10	－	－	－	－	－	－	－
	12	－	－	－	－	－	－	－
	14	－	－	－	－	－	－	－
	16	－	－	－	－	－	－	－
	18	－	－	－	－	－	－	－
D_1	10	－	－	－	－	－	－	－
	12	－	－	－	－	－	－	－
	14	－	－	－	－	－	－	－
	16	－	－	－	－	－	－	－
	19	－	－	－	－	－	－	－
$D_{0.5}$	10	－	－	±	±	＋	＋＋	＋＋
	12	－	－	－	－	－	－	－
	14	－	－	－	－	－	－	－
	16	－	－	－	－	－	－	－

果を掲げる。

a)　各種塩分濃度 (Cl 1～9‰) の汽水で形成された耐久卵の孵化増殖に対する高鹹水の影響

耐久卵の材料:　昭和 34 年 5 月 10～16 日に，Cl 1, 3, 5, 7, 9‰の緑藻 *Selenastrum gracile* の green water を培養液として形成された *Br. plicatilis* の耐久卵を，それが形成された，同塩分の稀釈海水に夫々浸漬し，5 カ月経過したものを供試した。これらの耐久卵を夫々 D_1, D_3, D_5, D_7, D_9 と略称する。

方法:　Cl 10, 12, 14, 16, 18‰の海水並に稀釈海水に，海産緑藻 *Chlamydomonas* を培養した green water を培養液とした。各 20 cc を 30 cc 容量の試験管にとり，耐久卵 D_1, D_3, D_5, D_7, D_9 を夫々 107, 67, 130, 142, 63個を入れた。試験管は 1 列に並べ，20W 2 本の昼光色蛍光灯で側面から連続的に照射した。水温は 23.0～29.2°C。

結果:　Table 11 に示した。

耐久卵の孵化増殖は，D_5, D_7, D_9 に見られ，D_1, D_3 には認め得なかつた。1 週間後に，沈積している耐久卵を検鏡したが，D_1, D_3 には孵化した脱殼，孵化過程にある卵も見出し得なかつた。それより塩分の小さい green water で形成された $D_{0.5}$ では，Cl 10‰に移したもののみに 3 日後から孵化増殖が見られているので，D_1, D_3 に全く孵化増殖の見られない原因は明かでない。

D_5 は Cl 10, 12, 14, 16‰で孵化増殖が見られたが，その程度は塩分が大きくなると逆に小さくなり，Cl 18‰では孵化は見られない。

D_7, D_9 は Cl 10～14‰, Cl 10～12‰で夫々孵化増殖が見られるが，Cl 16‰以上，Cl 14‰以上では認められない。

従つて全体的に見ると，Cl 5～9‰の汽水で形成された耐久卵を，Cl 10～18‰の green water に移した場合，孵化増殖の見られるのは，Cl 10～14‰の範囲で，それ以上では著しく阻害され，海水 (Cl 18‰) では全く孵化増殖は見られない。D_7, D_9 の耐久卵が，D_5 より孵化力が小さいのは，Cl 7, 9‰が養鰻池産の *Br. plicatilis* の増殖に対しては好適でなく，従つて形成された耐久卵の activity が衰えていたのではないかと考える。

b)　各種塩分の低鹹海水 (Cl 7～15‰) で形成された耐久卵の孵化増殖に対する塩分の影響

耐久卵の材料:　Cl 7, 9, 11, 13, 15‰の稀釈海水に *Chlamydomonas* を培養した green water 中で，昭和34年10月16～24日に形成された *Br. plicatilis* の耐久卵を集め，形成された培養液と同塩分の稀釈海水に夫々浸漬し，約 20 日経過した耐久卵を使用した。これを D_7, D_9, D_{11}, D_{13}, D_{15} と呼ぶことにする。

方法:　Cl 10, 12, 14, 16, 18‰の *Chlamydomonas* の green water を培養液とした。各 25 cc を 30 cc 容量試験管にとり，D_7, D_9, D_{11}, D_{13}, D_{15} を夫々，158, 184, 86, 20, 21個加え，恒温槽 (29°C) に入れ，ガラス窓を通して外部から，20W 昼光色蛍光灯で側上方から連続的に照射した。

結果:　Table 12 に示した。

各種塩分で形成された耐久卵の孵化増殖と，移された塩分との関係は，Table 12 に明かのように，結果は稍々不規則である。全体的に見ると，D_7, D_9 は Cl 14～16‰まで孵化増殖するが，D_{11}, D_{13}, D_{15} は海水でも孵化増殖する。特に D_{15} は Cl 10～18‰の全塩

Table 12. The effect of salinity change upon the hatchability of the dormant eggs of *Br. plicatilis* produced under various salinities (Cl 7, 9, 11, 13, 15‰).
The marks, ++++〜−, show the numbers of rotifer hatched out; ++++ 500–1000; +++ 100–500; ++ 50–100; + 10–50; ± 1–10; − none.
W.T. 29°C, thermostat in darkness.
Media: green water (*Chlamydomonas* sp.) of various salinities (Cl 10, 12, 14, 16, 18‰).

Dormant eggs	Cl ‰ Transplanted	Time in day								
		1	2	3	4	5	6	7	8	10
D_7	10	−	−	−	±	±	±	±	±	+
	12	−	−	−	±	±	±	±	±	±
	14	−	−	−	±	±	±	±	±	±
	16	−	−	−	−	−	−	−	−	−
	18	−	−	−	−	−	−	−	−	−
D_9	10	−	±	±	±	±	±	±	±	+
	12	−	±	±	+	++	+++	+++	++++	++++
	14	−	−	−	±	±	±	±	±	±
	16	−	−	−	±	±	+	++	+++	++++
	18	−	−	−	−	−	−	−	−	−
D_{11}	10	±	±	±	+	++	+++	++	+	±
	12	±	±	±	+	+	++	+	+	±
	14	−	−	−	±	+	++	+	±	±
	16	−	−	−	−	−	−	±	±	±
	18	−	−	−	−	−	−	±	+	++
D_{13}	10	−	±	±	+	++	+	±	±	±
	12	−	−	−	±	±	±	±	±	±
	14	−	−	−	±	±	±	±	±	±
	16	−	−	−	−	−	−	−	−	−
	18	−	−	−	−	−	−	−	−	−
D_{15}	10	±	±	+	++	+++	++++	++++	++++	+++
	12	±	±	+	++	+++	++++	++++	+++	+
	14	±	+	+	++	+++	++++	++++	++	+
	16	±	±	±	+	+	++	+++	++	±
	18	±	±	±	+	+	+	+	+	±

分に亘つてよく孵化増殖する。

c) 海水で形成された耐久卵の孵化増殖

耐久卵の材料: Cl 16 並に 18‰ の *Chlamydomonas* の green water で，昭和34年7月末から9月下旬に亘つて形成され，器底に沈積した *Br. plicatilis* の耐久卵を集め，藻類のフロックから分離して供試した。この耐久卵を D_{16}, D_{18} と略称する。

方法: Cl 16 並に 18‰の海水で，別に培養した *Chlamydomonas* の green water を培養液とし，各 50 cc を 200 cc 容量のコルベンにとり，夫々に D_{16}, D_{18} の耐久卵を少量加え，恒温槽 (29°C) に入れ，前述と同様に蛍光灯で連続照射した。

結果: Table 13 に示した。

Table 13. The hatchability of the dormant eggs of *Br. plicatilis* produced in the sea water (Cl 16 and 18‰).

The marks, ++++〜−, indicate the numbers of rotifer hatched out; ++++ >300; +++ 100-300; ++ 50-100; + 10-50; ± 1-10; − none.

W.T. 30°C; thermostat in darkness.

Media; green water (*Chlamydomonas* sp.) of the sea water (Cl 16 and 18‰).

Dormant eggs	Cl ‰ transplanted	Time in day								
		1	5	8	9	10	11	12	20	30
D_{16}	16	−	−	−	±	+	+	+	+++	++
D_{18}	18	−	−	−	−	−	±	+	+++	++++

D_{16} は9日後から孵化増殖がはじまり，20日後に多数となつた。D_{18}は稍々おくれて，11日後からはじまり，20〜30日後には著しい密度に達した。従つて海水で形成された耐久卵を海水の green water に入れた場合にも，明かに孵化増殖することが分る。しかし汽水で形成された耐久卵に比べて孵化増殖はおそいようである。

d) 養鰻池底泥中の耐久卵の孵化増殖に対するす塩分の影響

汽水養鰻池の底泥上には多数の *Br. plicatilis* 耐久卵が分布し，且つこれらの耐久卵は容易に孵化游出することは既に報告した[20]。この底泥中の耐久卵を海水培養の種苗として利用する方式を明かにするために本実験を行つた。

底泥の材料: 三重県楠町の S_2 池，河芸町の N_1 池の風乾泥を使用した。

底泥	耐久卵数/g	採泥日附	塩分(Cl ‰)
N_1	38.8	1-XII-'59	6.61
S_2	94.5	〃	2.96

蒸溜水，Cl 1, 3, 5, 7, 9, 11, 13, 15‰の稀釈海水を，N_1 の場合は 100 cc 容量のコルベンに 50 cc, S_2 の場合には 200cc 容量のコルベンに 100 cc 宛とり，N_1 は夫々 3 g, S_2 は夫々 2 g の風乾泥（乾固前に塊をよくほぐしておく）を加えて，恒温槽（28°C, 暗黒）に保つた。風乾泥は採泥後7日に使用した。

結果: Tables 14〜15 に示した。

N_1 の底泥からは，Cl 11‰以下の塩分でよく孵化し，Cl 11〜13‰でも少量孵化した。S_2 の底泥からも，N_1 と同様に，Cl 11‰以下で極めてよく孵化し，Cl 13〜15‰でも相当量が孵化した。しかし Cl 17‰の海水では孵化は認められなかつた。蒸溜水を加えたものでも孵化游出が見られているが，これは風乾泥の塩分の溶出によつて汽水になつているためである。

養鰻池底泥中の耐久卵を培養種苗として使用する場合の留意点として次のことが挙げられる。

i) 新鮮な風乾泥を用いる。1年以内では孵化するが，それ以上経過したものは，風乾泥のみでなく，湿泥を用いても孵化しない。

Table 14. The effect of salinity upon the hatchability of the dormant eggs of *Br. plicatilis* in dry mud of the eel-culture pond (Pond N_1 in Kawagechô, Mie Pref.)
W. T. 28°C, thermostat in the darkness.
Media: diluted sea water of various salinities (Cl 0.36-17‰).
The marks, ++++～−, show the numbers of rotifer hatched out; ++++ 100; +++ 30-50, ++ 10-30; ± tr. − none.

Cl ‰ transplanted	Time in day				
	1	2	3	6	8
D.W. (0.36)	+	++	+++	+++	+++
1	++	++	++++	+++	+++
3	++	++	++	+	±
5	++	++	++	+	±
7	++	++	++	+++	+++
9	+	+	++	+++	+++
11	+	+	++	++	++
13	±	±	+	±	±
15	−	±	±	±	−
17	−	−	−	−	−

Table 15. The effect of salinity upon the hatchability of the dormant eggs of *Br. plicatilis* in dry mud of the eel-culture pond (Pond S_2 in Kusu-chô, Mie Pref.).
W.T. 29°C, thermostat in the darkness.
Media: diluted sea water of various salinities (Cl 0.28-17‰).
The marks, ++++～−, show the numbers of rotifer hatched out; ++++ >1000; +++ 500-1000; ++ 100-500; + 10-100: ± <10; − none.

Cl ‰ transplanted	Time in day				
	1	2	4	6	8
D.W. (0.28)	±	+	++	+++	+++
1	±	++	++++	++++	++++
3	+	++	++++	++++	++++
5	+	++	++++	++++	++++
7	+	++	++++	++++	++++
9	±	±	++++	++++	++++
11	±	±	++	++++	++++
13	−	−	±	+++	+++
15	−	−	±	++	++
17	−	−	−	−	−

ii) 底泥中における *Br. plicatilis* の耐久卵の密度が相当に大きいこと，温水期に本輪虫が多数棲息していた相当に塩分の濃い養鰻池の底泥を用いる。

iii) 容器は底面積が広く，底泥中の耐久卵をなるべく液と接するようにする。これは孵化個体の水中游出を容易にするためである。

iv) 泥量を余りに多くしない。泥中の豊富な有機物が腐敗し，甚だしい腐敗の場合に

は孵化は極めて悪い。液が僅かに乳濁する位がよい。加える泥量は液量並に泥中の有機物量によつて異るのはいうまでもないが，2〜3 g/100 cc 位が適当のようである。乳濁し懸息があつても差支えない。

v）孵化した amictic female を green water に subculture して種苗に用いる。green water 底泥を加えると，藻類の細胞が泥粒子に吸着され，沈積し，腐敗を増大し好ましくない。

e）総　括

Cl 1〜15‰で実験室で形成された *Br. plicatilis* の耐久卵，並に Cl 3‰程度の養鰻池底泥中の耐久卵を，Cl 10〜18‰に移した場合の孵化，増殖に関する上述の実験結果は次のように総括出来る。

耐久卵の孵化増殖は，形成された塩分並びに耐久卵が移された塩分濃度によつて異り，Cl 11‰以上の塩分で形成された耐久卵は，Cl 18‰でも充分孵化増殖出来る。しかし Cl 9‰以下の塩分で形成された耐久卵は，徐々に孵化増殖の出来る塩分限界はいく分小さくなるが，少くとも Cl 10〜12‰ではよく孵化増殖出来，また Cl 3‰前後の養鰻池底泥中の耐久卵も Cl 10〜12‰では充分に孵化増殖する。従つてこの点は養鰻池の略々同塩分に棲息した amictic female に比して，耐久卵の方が高塩分に対する抵抗性が強いといえる。このことは，耐久卵を種苗として用いると，僅かの subculture で海水培養の種苗を作ることの可能性を示している。前述の S_2 池の底泥中の耐久卵を用いると，Cl 10〜13‰ ならば，1 回の培養で種苗が得られる。

3.　耐久卵の保存について

Br. plicatilis の耐久卵は，前掲のように，乾燥に対する抵抗性が極めて強く，風乾によつて 1 年以内は保存出来る[17]。実験室の水槽で形成され，器底に沈積した耐久卵は D♀ の死滅後に，上液を傾瀉あるいはサイフォンによつて棄却し，小型容器に集める。この場合耐久卵は藻類のフロックと混在する。このままで濾紙上で風乾すると，耐久卵はこのフロックにからまり，孵化させるために培養液に移しても，からまつたままで，游離せず，孵化游出が困難となり成績はよくない。フロックを硝子棒で無理してほぐすと，その機械的作用で耐久卵を損傷する。この場合，粗砂で，この耐久卵とフロックの混合物を沪過し，よく混合した後に，風乾しておくと，これを液に移した場合，容易に分離し成績はよい。養鰻池底泥を用いる場合にもこの点の注意が肝要で，風乾して乾固する前に，稍々水分を含んでいるときに，手で塊をほぐしておく。乾固したものは液に入れても容易に細かくならない。塊を乳鉢ですり潰したりすると，耐久卵を損傷するおそれがある。

耐久卵の保存法は他にも考えられるが，これらについては未だ充分に検討していない。

V. 今 後 の 問 題 点

Br. plicatilis を海産の水産動物幼生の餌料として使用するには，大量を必要とする。本種の大量培養法を確立するには，今後更に次の諸問題の解決が必要であらう。

第 1 は，輪虫の餌料としての micron-algae の大量培養の問題である。海産緑藻の *Chlamydomonas*, *Dunariella* は，*Br. plicatilis* の海水培養の餌料として適当であるが，輪虫の大量培養には先づこれらの micron-algae をいかにして大量に得るかが問題である。大量の micron-algae の green water が簡単に得られるならば，本輪虫の大量培養

の可能性がある。micron-algae の大量培養には，現在日本クロレラ研究所において，クロレラの室内培養に使用されている培養管の原理を応用出来よう。この装置は 40W 蛍光灯を培養管に挿入し，下部から CO_2 を補給するものである。この場合，大量の海水の殺菌法も考える必要がある。

第 2 は，海水培養の *Br. plicatilis* の種苗の確立の問題である。前述したように汽水産の本種を徐々に高塩分に適応させると，海水でも充分培養できるようになる。しかし高塩分での増殖速度は小さくなる欠点がある。海水培養においても汽水と同様の増殖速度の早いことが望ましい。そのような海水培養の種苗の確立が今後必要であらう。しかし現在でも Cl 10～12‰の低鹹水の green water で輪虫を培養し，ネットを用いて，餌料として給餌すれば，最も簡単で能率的であり，実際的にも支障はあるまい。

第 3 は，輪虫耐久卵の大量形成法とその保存の問題である。耐火卵は乾燥に対する抵抗性が強く，風乾して 1 カ年位は保存出来る。耐久卵が確保されると，brine shrimp のそれと同様に，どこでも随時に孵化個体を直接餌料としても，また培養の種苗としても利用出来，最も簡便となる。その意味からも耐久卵の大量形成法は重要であらう。これに関連し，汽水養鰻池底泥中の耐久卵を砂泥から分離する方法も検討する価値のある問題であろう。

第 4 は，輪虫の餌料効果の問題である。*Br. plicatilis* を海産水産動物の幼生の餌料として飼育を試みた報告は現在までにない。従つてこの輪虫の餌料効果は未知数である。実際の飼育者の餌料試験の結果が俟たれる。

最後に，本研究は大島教授を主任とする文部省科学試験研究費「餌料微生物の培養種保存とその餌料効果に関する研究」の 1 分担として行つたものである。種々の有益な助言を与えられた東京大学農学部大島泰雄教授，平野礼次郎氏，並に山口県内海水産試験場前川兼佑場長に深甚の謝意を表します。

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養鰻池における *Microcystis* の分布，特に増殖に対する塩分・水温・栄養塩類の影響

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The Distribution of *Microcystis* in Mixohaline Eel-Culture Ponds, With Special Reference to the Effects of Salinity, Temperature and Nutrients upon the Growth

(*With 14 Text-figures and 1 Table*)

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Résumé

Microcystis aeruginosa is one of the dominant species of the phytoplankton in the eel-culture ponds in the summer time, and regarded important for the eel-culture.

This paper shows the results of the field survey on the relations of distribution and salinity and on the seasonal succession of *Microcystis aeruginosa* and of the experimental researches of the influences upon the growth of the salinity, water temperature, nutrients, through the pure culture of *Microcystis aeruginosa*.

1. The upper limit of salinity for the distribution of *Microcystis aeruginosa* is Cl 6‰, but it is dominant in the eel-culture ponds with the salinity lower than Cl 1‰.

2. In the seasonal succession of *Microcystis aeruginosa*, it shows the extinction with the salinity more than Cl 5‰, poor in its growth at Cl 3–5‰, the best under Cl 3‰.

3. As for the salinity influencing on the growth of *Microcystis aeruginosa*, the experimental results tell that the growth shows the best at Cl 0.1‰ and that with the increase of the salinity the growth becomes much the worse. This tendency shows that this is in accordance with that of the field survey.

4. The optimum water temperature for the growth of *Microcystis aeruginosa* is 20–30°C. But the time of the occurrence and disappearance differ with the enviromental conditions of the eel-culture waters.

5. The optimum concentration of nutrients suitable for the growth of *Microcystis aeruginosa* is 5 ppm in N, 1 ppm in P, 700–1500 ppm in K, 3 ppm in Fe and 3% of soil extract. But no conspicuous difference is caused with Ca and Mg within 0–100 ppm.

6. In the eel-culture pond, the salinity in the pond water is the most important as the limiting factor to the growth of *Microcystis aeruginosa*.

7. For the growth of *Microcystis aeruginosa* in the eel-culture pond it is the most essential to keep the salinity of the water under Cl 1‰ and never to raise it.

I 緒　　　言

養鰻池では *Microcystis* は一般に「アオコ」と呼ばれ，夏期に卓越する植物プランクトンの代表的な種類の一つである。

ウナギ養殖が植物プランクトンを主体とした池水条件に依存されることから，植物プランクトンの重要性が論じられているが[23]，特に養魚上 *Microcystis* は池水の酸素供給源としてすぐれ，ひいてはウナギの摂餌，収量に影響をもたらすと言われている[10][20]。

養鰻池における *Microcystis* についての研究は野外調査を主体に進められ，その出現時期は水温 18°C 以上であつて[10]，初夏から秋にわたり卓越するが[25]，「水の華」を形成している時の水温は 28〜30°C であること[30]，あるいは池水の塩分が制限要因となつて静岡県では Cl 1 g/L が分布上限とされ[10]，愛知，三重では Cl 5‰ であること[15][22]，また "水変り" の殆んど起らない池は *Microcystis* が卓越すること[25] が明らかにされ，更に実験的には "水変り" の制御に対する *Microcystis* の重要性[12]，懸濁時に酸素放出量が大であること[27]など，多くの研究がなされて来た。

しかしながら池水管理の実際においては *Microcystis* を池水から分離･培養することによつて，その増殖を支配する要因について実験的に解明しなければならない多くの問題がある。

筆者は三重県養鰻池の *Microcystis* の分布，季節的消長についての野外調査を行い，更に *Microcystis* を分離･培養し，その増殖に及ぼす塩分，水温，栄養塩類の影響について実験的研究を行つたのでその結果について報告する。

本研究に際し終始御懇切な御指導を賜り，更に本稿を校閲して戴いた本学陸水学教室　伊藤隆博士，並に培養について御指導賜つた京都大学大津臨湖実験所　根来健一郎博士，東京大学応用微生物研究所　服部明彦助教授に対し感謝いたします。

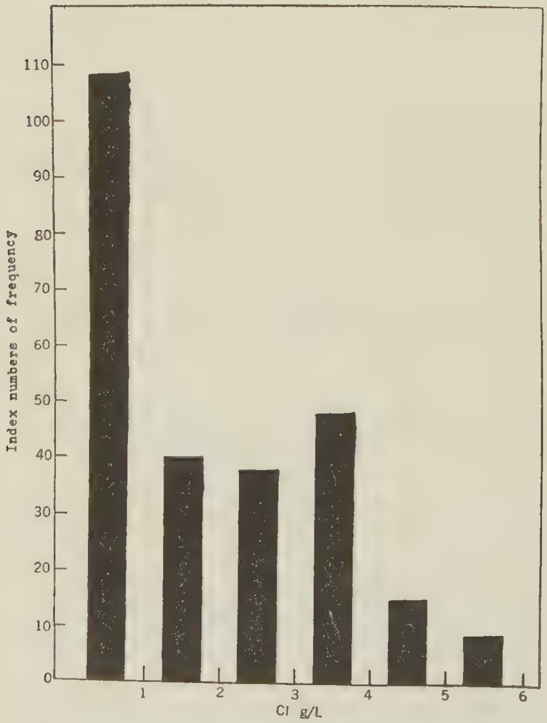

Fig. 1. The relation between the relative frequency of *Microcystis aeruginosa* and salinity of mixohaline eel-culture ponds in Mie Prefecture.

II 野　外　調　査

1. 三重県養鰻池における Microcystis の分布と塩分との関係

養鰻池の多くは海岸地方にあるため，池水は可成りの塩分を含み「汽水」に属する。

筆者は三重県養鰻池を主とする汽水性養魚池の植物性プランクトンの調査を行つたが[15]，その結果によると *Microcystis aeruginosa* は塩素

量 6‰ 以下の 78 養鰻池から出現し，また *Microcystis* の量と塩分との関係について頻度指数で示すと Fig. 1 に示すように量的には Cl 1‰ 以下の低鹹池に特に卓越し優占種となる傾向があつて，池水の塩分は *Microcystis* の分布を決定する重要な要因の一つと考えられる。

2. 養鰻池における Microcystis の季節的消長

1955 年以来三重県下の養鰻池において水質，プランクトン，水変りなどを明らかにするため，継続調査を行つて来たが[13]，それらの中で *Microcystis aeruginosa* の出現した 9 養鰻池について，その季節的消長と水温，塩素量との関係を整理すると次のようになる。*Microcystis* の定量は 1956 年度の M_2 池及び 1958 年度 S 池では細胞計数法で表現するだけの増殖量に至らなかつたので頻度指数を適用し，その他のものについては細胞計数を行い球曲線法で図示した。

1) M_2 池 (Fig. 2)

M_2 池は津市島崎町の志登茂川河口の南岸に位置する養鰻池である。調査は 1956 年 4 月から 12 月にわたつて行つた。*Microcystis* は 7 月下旬から 11 月中旬まで出現し，最もよく増殖したのは 8 月中旬から下旬にわたる期間であつた。出現時の水温は 30°C，11 月下旬の消滅時の水温は 14.1°C であつた。この間 9 月下旬から 10 月初旬に一時的ではあるが *Microcystis* の消滅が見られた。これは当時イカリ虫の駆除のために海水を注入したため，池水の塩分が急激に増加したことに原因している[14]。

M_2 池は 1955 年度には継続的調査を欠くが，6 月，9 月，10 月の断片的な調査結果では *Microcystis* は認められず *Synechococcus* sp. *Merismopedia tenuissima* などが優占種であつた。また当時の池水の塩素量は 3.55‰ であつた。

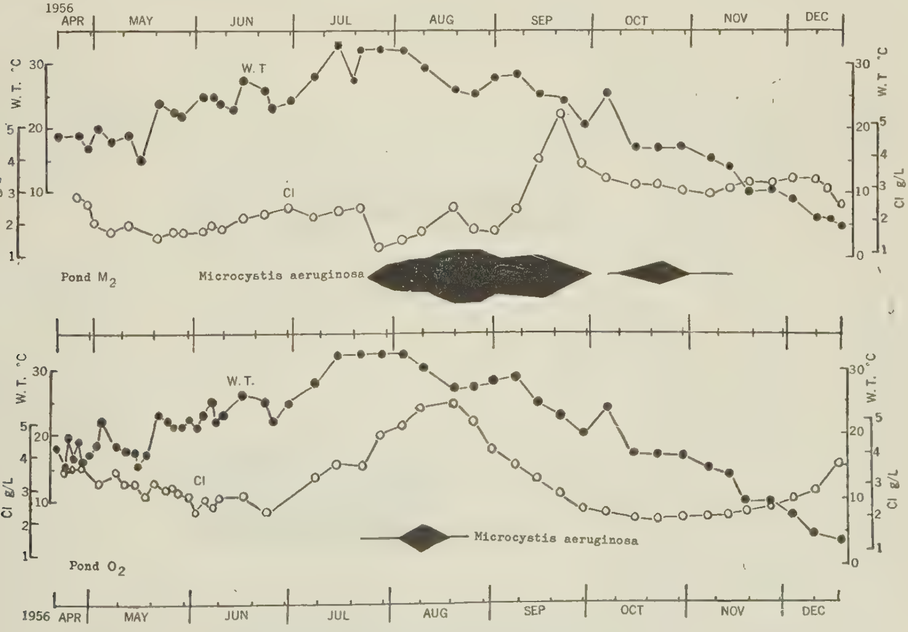

Fig. 2. The seasonal successions of *Microcystis aeruginosa* in ponds M_2, O_2 in Tsu City, 1956.

2) O_2 池 (Fig. 2)

O_2 池は志登茂川河口から約 2.5 km 上流に位置する養鰻池である。調査は 1956 年 4 月から 12 月に亘つて行つた。*Microcystis* の出現は 7 月中旬から 8 月中旬にわたる約 1 カ月間で量的にも貧弱であつた。出現時の水温は 30°C 前後で，最高水温期であり，またその時の池水の塩素量は 3.63～5.52‰ と O_2 池の 1956 年度における最も高鹹度の時期であつた。この池は 1955 年度に継続的調査を行つたが *Microcystis* は全く出現せず，塩素量は 4～5‰ であつて 1956 年度に較べて高鹹であつた[13]。

3) S 池 (Figs. 3, 4)

S 池は三重郡楠町吉崎にあり，1958 年，1959 年の 2 ヶ年にわたつて調査を行つた。1958 年には S_2, S_3, S_4 の 3 面の養鰻池について 3 月 20 日から 12 月 15 日まで，また 1959 年度には S_2, S_3, S_4, S_t の 4 面で 5 月 1 日から 12 月 11 日まで，原則として週 2 回調査した。これらの養鰻池は隣接し，同一年度内における水温，塩素量は池に

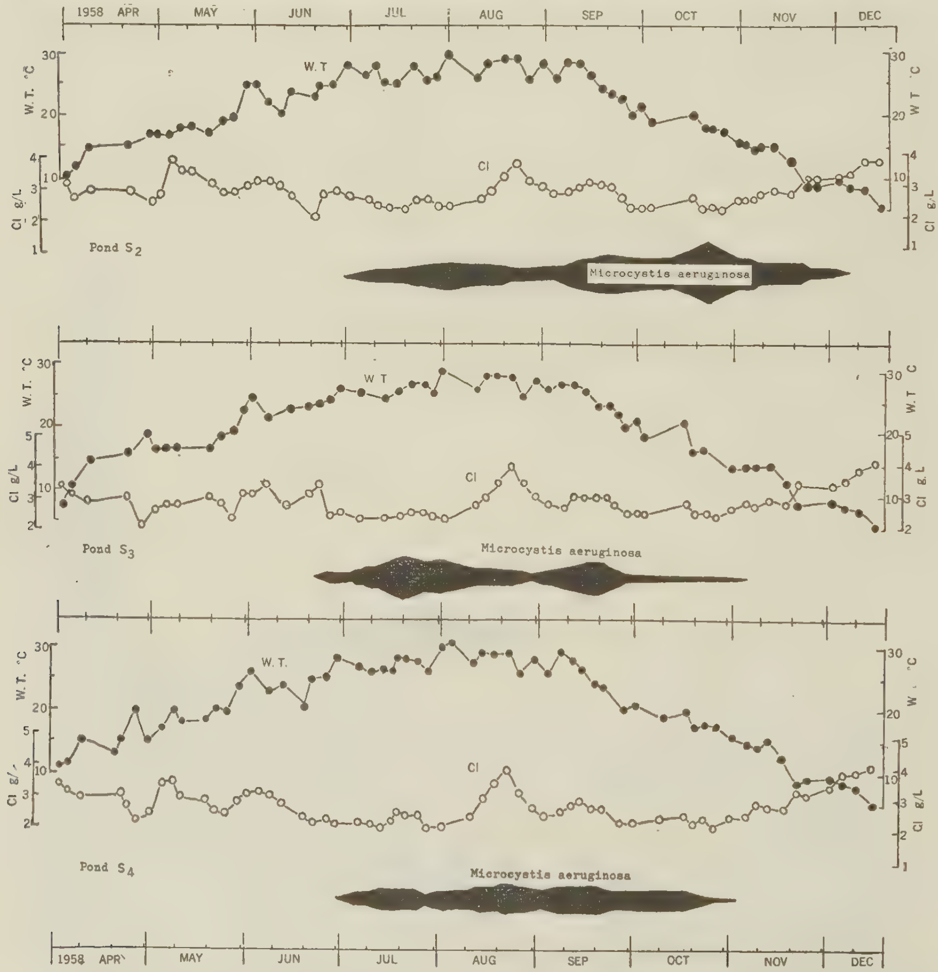

Fig. 3. The seasonal successions of *Microcystis aeruginosa* in ponds S_2, S_3 and S_4 in Kusu-chô, 1958.

よる差はなく，またその季節的変化の傾向も類似しているのでこれらを調査年度別に総括すると次のようになる。

i) 1958 年度における季節的消長 (Fig. 3)

Microcystis aeruginosa の出現は S_3 池が最も早く 6 月中旬 (W. T. 23°C) であつたが，S_2, S_3 池は 7 月初旬殆んど同時に出現した (W. T. 25°C, 28°C)。消滅の時期は S_2

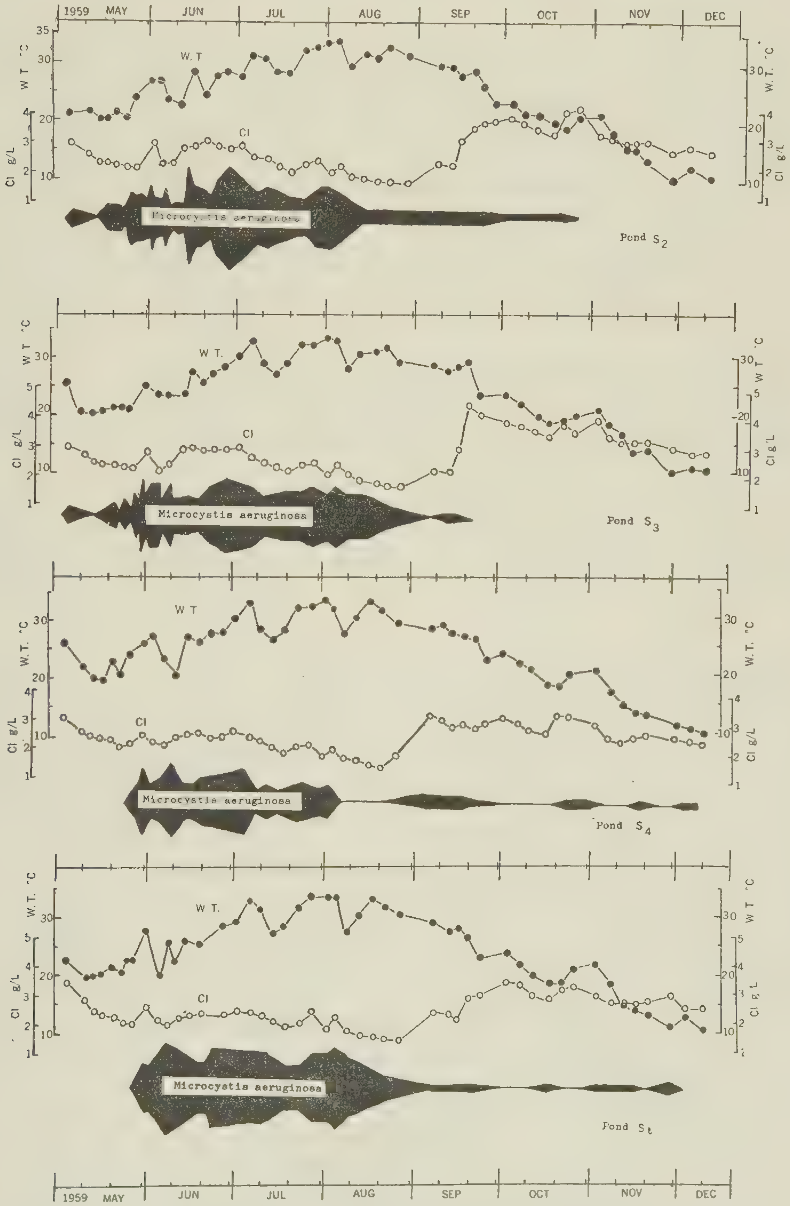

Fig. 4. The seasonal successions of *Microcystis aeruginosa* in ponds S_2, S_3, S_4 and S_t in Kusu-chô, 1959.

池では 12 月初旬 (W. T. 8.6°C), S_3, S_4 池は 11 月初旬であつた (W. T. 夫々15°C)。池水の塩素量は3池とも 2～4‰の範囲にあり,特に8月中旬に一時的に塩分が多くなつているが，これは高鹹用水の注入のためであり，池水の塩素量の最大は S_2 池では 3.78‰, S_3 池は 4.02‰, S_4 池は 3.89‰ に達し，S_2, S_3 池では *Microcystis* は幾分衰えたが前述の M_2 池のように消滅するには至らず，再び増殖した。

ii) 1959 年度における季節的消長 (Fig. 4)

1959 年度は前年に較べ S_2, S_3, S_4, S_l 池とも *Microcystis aeruginosa* の出現は早く S_2, S_3 池では 5 月初め (W. T. 21°C, 25°C) から S_4, S_l 池は 5 月中旬 (W. T. 21°C, 23°C) から出現した。また増殖量も前年に較べ非常に大きく，S 池の優占種として 8 月中旬まで持続した点は M_2, O_2 池および 1958 年度の S 池と著しく対照的である。8 月中旬以降 *Microcystis* の急激な減少が各池に見られたが，これはイカリ虫駆除のための海水注入による急激な塩分増加の影響と考えられる。その後には著しい増殖は見られず S_2 池では 10 月下旬 (W. T. 22°C) に，S_3 池では 9 月下旬 (W. T. 28°C) の伊勢湾台風後に消滅した。また S_4 池は僅かながらも 12 月中旬 (W. T. 10°C) まで存続し，S_l 池では 12 月初旬に消滅した (W. T. 13°C)。

池水の塩素量は *Microcystis* の著しく増殖した 5 月から 8 月初旬までは各池とも 2～3‰ の範囲にあり，淡水注入によつて一時的に 1.5‰ 近くまで減少したが，その後の著しい増加（高鹹用水による）によつて S_2 池では最高 4‰ に達し，それ以降 *Microcystis* の消滅した 10 月下旬までは 3～4‰ の範囲であつた。

S_3 池においては最高 4.5‰ に達し，その後 *Microcystis* は消滅した。S_4, S_l 池の塩素量の最大値は S_2, S_3 池より低く，夫々 3.3‰, 3.4‰ であつて *Microcystis* は量的には貧弱であつたが 12 月まで持続した。

3. 要　約

上述の野外調査の結果を要約すると次のようになる。

1) 三重県養鰻池に出現する *Microcystis aeruginosa* の分布と塩分についての野外調査の結果は，Cl 1‰ 以下の低鹹養鰻池に卓越し，池水の塩分が濃くなるに伴つて量的に著しく減少し Cl 6‰ を分布の上限とする[15]。このことは *Microcystis aeruginosa* の季節的消長と塩分との関係についての調査結果，即ち Cl 5‰ 以上では消滅すること，Cl 3～5‰ ではその増殖が悪いこと，調査した養鰻池での最低塩素量である 2～3‰ の範囲では増殖は著しく，優占種となるとの結論とほぼ一致する。

2) *Microcystis aeruginosa* の出現は水温 20°C 以上であるが，出現時期は 5 月初めの場合もあり，また水温が 30°C に達する 7 月中旬の場合もある。しかし，池水の塩分の急激な変化によつて高鹹化した場合には夏期にでも消滅する。水温の低下に伴つて量的にも貧弱となつて 12 月中旬まで存続する場合もあるが 20°C 以下になつた 10 月中旬以降の *Microcystis aeruginosa* の現存量は極めて貧弱である。

III 実験的研究

養鰻池の *Microcystis* に関しては培養実験による生理･生態学的研究の重要性が認められながらも[26] 培養が困難であつたために進展せず，唯，須藤[28] によつて *Microcystis* の

分離，培養の方法が明らかにされたに過ぎない。しかしながら米国においては既にGerloffらは *Microcystis aeruginosa* の増殖に対する制限要因を明らかにするために純粋培養を行い[3)4)]，その栄養生理に関して成果をあげており[5)6)7)]，その大要については須藤[29)]によつて紹介されている。

筆者は 1959 年 6 月以来 *Microcystis aeruginosa* を養鰻池から分離・培養を行い，その増殖に対する塩分，水温，栄養塩類の影響について実験を行つた。

1. 培　養　法

Microcystis aeruginosa は寒天培養による分離が不可能であつたので，養鰻池に著しく増殖した藻種を採集し，実験室で静置し，浮上した大型のブロック状の藻種をミユラーガーゼで掬い上げ，それを数回 subculture し，更に遠心分離によつて *Microcystis* 以外の生物を沈澱させ浮游した *Microcystis* を更に subculture することによつて単一培養に成功した。

培養液は Detmer 液[1)2)]を改良して用いた。その組成は次の通りである。

NH_2CONH_2	0.022 g
K_2CO_3	0.530 g
$CaCl_2$	0.050 g
$MgSO_4 \cdot 7H_2O$	0.125 g
K_2HPO_4	0.125 g
NaCl	0.050 g
Fe citrate	3 mg
Citric acid	3 mg
Soil extract	5%
H_2O	1000 cc

培養液の pH は 7.5 に調整

Gerloff[4)] らの用いた Chu No. 10 の培養液も用いたが結果は Detmer が，永続性があつた。

光源には 60W 普通電球を用い，約 60 cm 上方から照射した。培養液の殺菌には紫外線殺菌燈 (2537Å) を使用した。

Microcystis の定量には沈澱量を用いた。固定には稲葉[8)] の氷醋酸を抜いたブアン液を用い，ヘマトクリート(0.025 cc 容量，0.001 cc 目盛) を使用し，遠心分離 (3000 回転/min., 15 分間) した沈澱量から 1 *l* 当りの沈澱量を算出した。

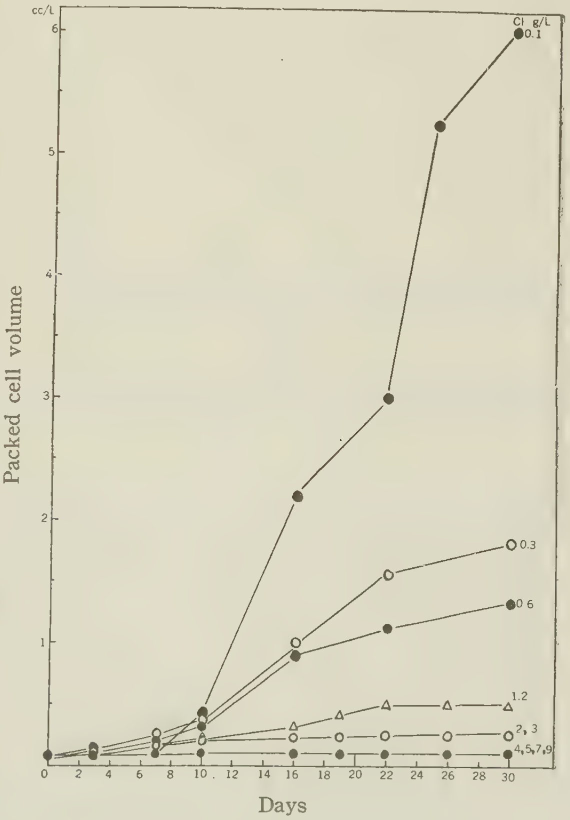

Fig. 5. The effect of salinity upon the growth of *Microcystis aeruginosa*.

2. Microcystis aeruginosa の増殖に及ぼす塩分の影響

Allen の人工海水を作り，夫々所定の塩分濃度に稀釈し，各々に Detmer 改良液の所定濃度の栄養塩を加え，全容量を 300 cc とし，500 cc 入り三角フラスコを使用した。

実験期間は 1959 年 10 月 30 日～11 月 29 日の 30 日間，水温は 30±1.5°C に保つた。

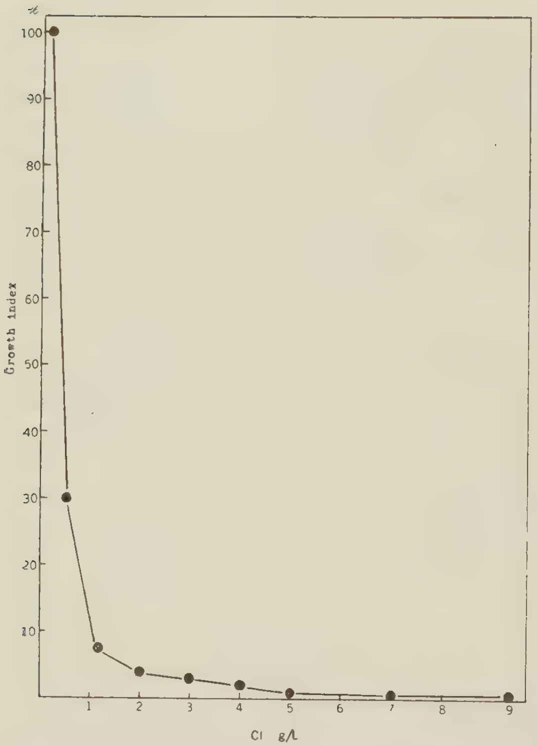

Fig. 6. Maximum growth of *Microcystis aeruginosa* at various salinity.

実験結果は Figs. 5, 6 に示した。Cl 0.1‰ では最高 6.00 cc/L に達したが Cl 0.3‰, 0.6‰ では増殖は著しく低下し，夫々 1.75 cc/L, 1.30 cc/L となり，それ以上の塩分濃度では増殖量は更に低下した。Cl 4‰ 以上では増殖量は沈澱量で表すに足る量に達しなかつたが顕微鏡による観察結果では Cl 7‰ までは微かながら *Microcystis* の suspend するのが認められた。

また Cl 9‰ 以上では全く増殖せず，細胞は黄変し沈澱した。

3. Microcystis aeruginosa の増殖に及ぼす水温の影響

実験は 1960 年 2 月 13 日～3 月 2 日にわたつて行つた。培養液は所定の Detmer 改良液を用いた。培養には 4 個の恒温槽を使用し，17°C, 23°C, 28°C, 36°C に保ち，更に室温で培養したもの (12～15°C) を最低水温とし，水温を 5 段階に分けて実験を行つた。実験結果は Fig. 7 に示した。

室温培養 (12°C～15°C) では多少増殖の傾向が見られたが，培養液が *Microcystis* の増殖によつて緑色を呈するに至らず，比較的大型の colony が沈澱した。

17°C では *Microcystis* は 2 週間後頃から増殖が始まり，藻種は水面に浮上し層状になるのが観察された。培養 24 日後には 2.90 cc/L に達し，それ以降増殖は停止した。

23°C では *Microcystis* は 7 日後から著しく増殖し，増殖初期には藻種は上層部に浮上し層状となるが培養後期には培養液全体に分散し，且つ鮮かな緑色を呈した。

28°C では 23°C と同様 7 日後から著しく増殖し始めた。20 日後までの増殖速度は 23°C と大差ないが，その後の増殖速度は 23°C の場合より大きく，30 日後には最大 12.00 cc/L に達し，培養液は著しい深緑色を呈した。

36°C では初期には他と同様に増殖の傾向が観察されたが 7 日以降，増殖は停止し，そ

の後は大型のブロックとなつて器底に沈降し，遂には黄変した。

以上の実験結果から *Microcystis* の増殖に対する適温は 23°C と 28°Cであるが，保存培養は常に 30°C～32°C の水温で行つており，また III-2 における増殖に対する塩分の影響の実験は 30±1.5°C の水温条件で行われたものであり，一方 17°C の実験でも幾分増殖することから，*Microcystis* の増殖適温は 20°C～30°C の範囲と考えられる。

4. Microcystis aeruginosa の増殖に対する栄養塩類の影響

Microcystis の増殖と栄養塩の種類，並に濃度の関係を明らかにするため，N, P, K, Mg, Ca, Fe, Soil extract の 7 種について実験した。培養条件については III-1 で述べた。水温は 30°C に保つた。pH はアルカリに傾くものは HCl，酸性に傾くものは K_2CO_3 で調整し pH=7.5～8 に保つた。あらかじめ実験の目的とする栄養塩欠除の培養液を作り紫外線殺菌燈を 5 時間照射し（殺菌効果を上げるために培養液の深さを浅くし，数回振盪した）その後対照とする栄養塩を所定濃度加えた。

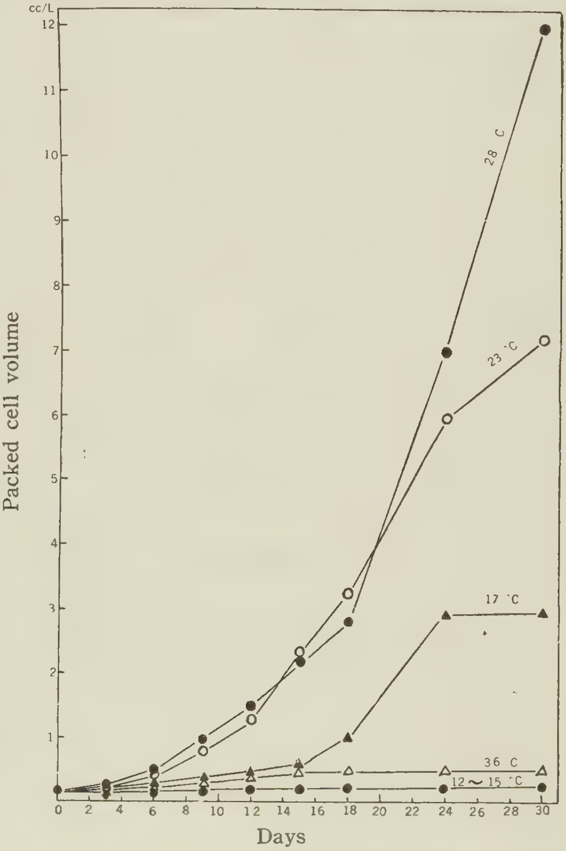

Fig. 7. The effect of temperature upon the growth of *Microcystis aeruginosa*.

1) 窒 素 N (Fig. 8)

窒素源としては尿素 (NH_2CONH_2) を用いた。培養初期には N=0.5, 1, 5, 10, 20 ppm では同様の増殖傾向を示したが，20 日後には N=5, 10 ppm の増殖が最もよく，夫々 7.20 cc/L, 5.50 cc/L を示し，N=0, 0.1, 0.5 ppm 及び 70 ppm の増殖量は著しく悪かつた。

2) 燐 P (Fig. 9)

燐の供給源としては K_2HPO_4 を使用した。Fig. 9 に明らかのように，P=0.1～10 ppm の増殖は良好で特に P=1 ppm の増殖は著しく，最大 7.20 cc/L に達した。

3) カリウム K (Fig. 10)

カリウムの供給源には K_2CO_3 を使用した。培養 14 日間の増殖量を比較すると K=1500 ppm までは添加量に応じて増殖量も増加するが，K=2000 ppm では増殖が低下した。最も良好であつたのは K=700 ppm の 6.60 cc/L，1500 ppm の 6.30 cc/L である。

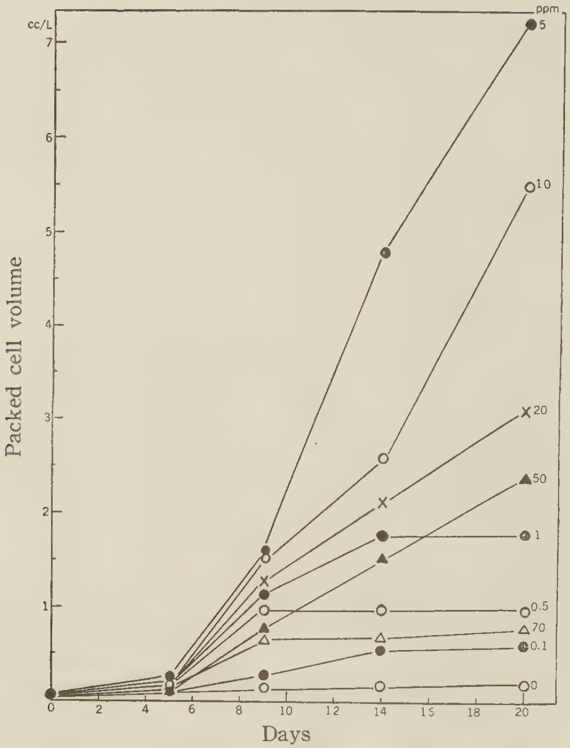

Fig. 8. Growth of *Microcystis aeruginosa* in various concentrations of nitrogen.

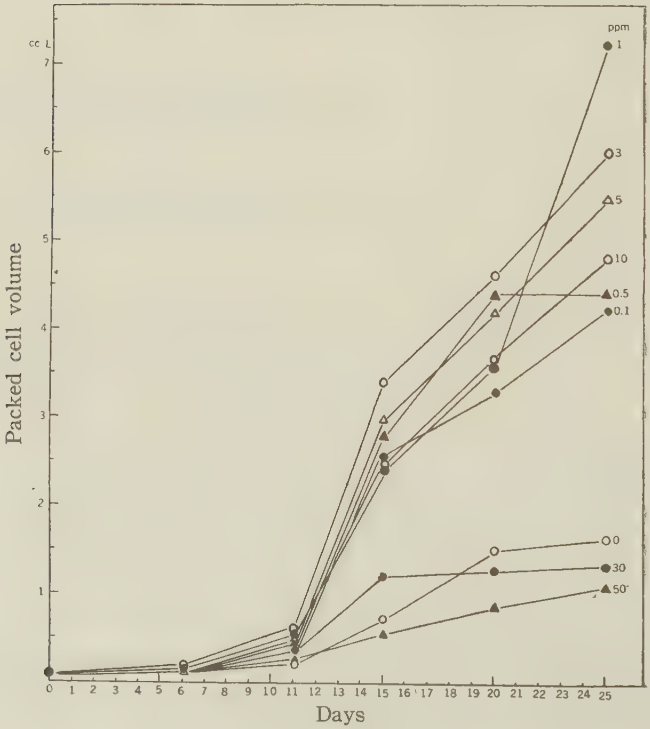

Fig. 9. Growth of *Microcystis aeruginosa* in various concentrations of phosphorus.

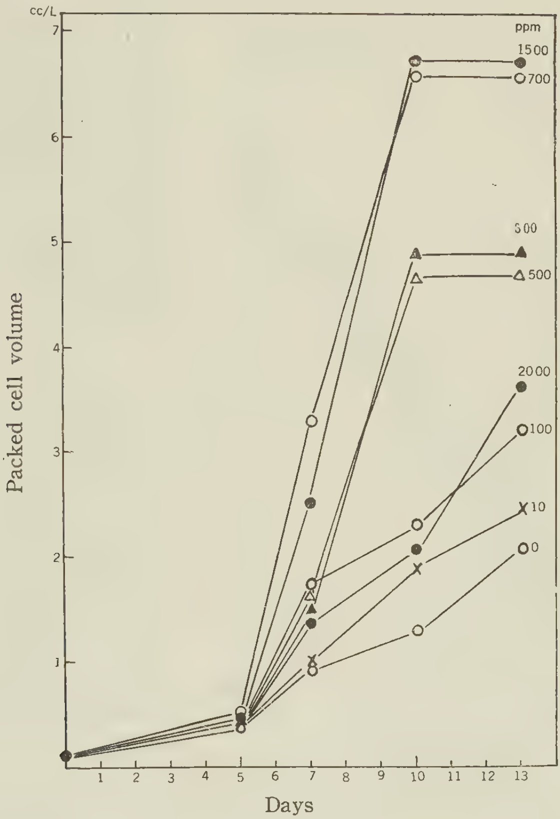

Fig. 10. Growth of *Microcystis aeruginosa* in various concentrations of potassium

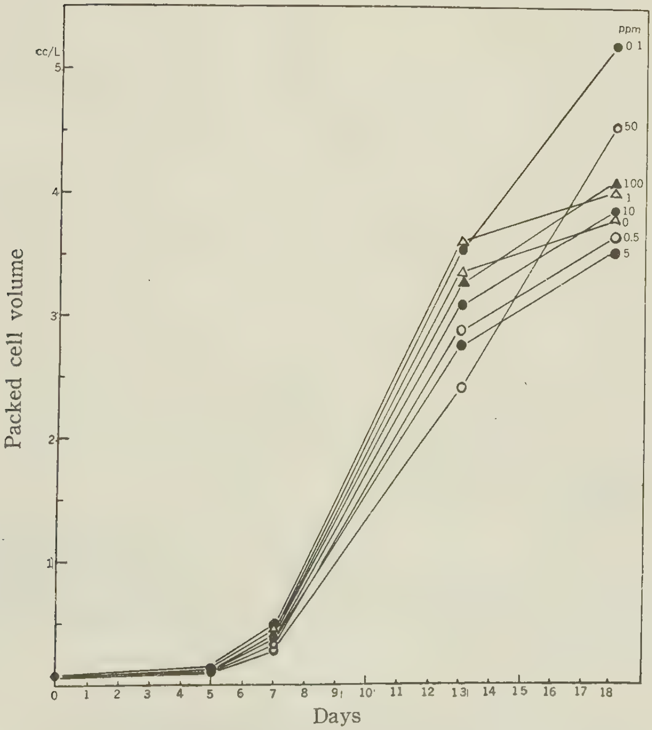

Fig. 11. Growth of *Microcystis aeruginosa* in various concentrations of magnesium.

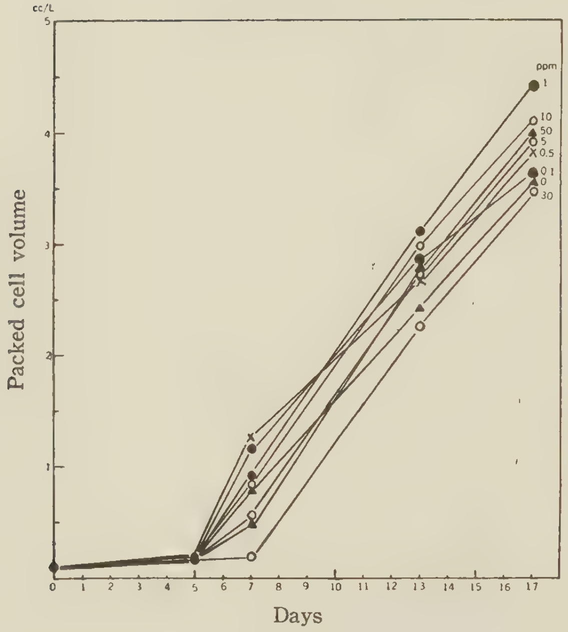

Fig. 12. Growth of *Microcystis aeruginosa* in various concentrations of calcium.

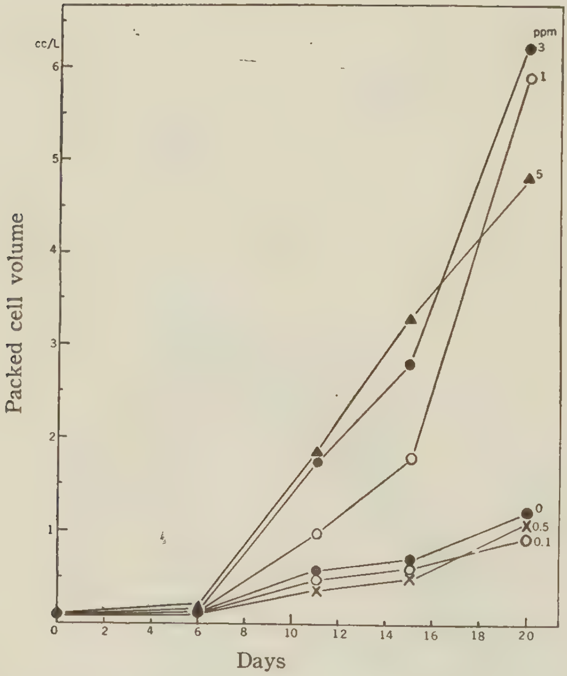

Fig. 13. Growth of *Microcystis aeruginosa* in various concentrations of iron.

4) マグネシウム Mg (Fig. 11)

マグネシウム源として $MgCl_2 \cdot 6H_2O$ を使用した。18 日間の実験で Mg=0.1 ppm の増殖量が 5.20 cc/L の最大であつたが全体的には Mg=0〜100 ppm の範囲では増殖に対する濃度差の影響は顕著ではない。

5) カルシウム Ca (Fig. 12)

カルシウム源として $CaCl_2$ を用いた。Mg の場合と同じように，18 日間の実験では 0〜50 ppm の範囲では Ca の濃度差による増殖量に顕著な差異は認められず 3.40〜4.40 cc/L であつた。

6) 鉄 Fe (Fig. 13)

鉄の供給源には $FeCl_3$ を用いた。Fe=5 ppm の添加によつて培養液は微かに赤褐色に着色し，それ以上の濃度では沈澱が生ずるので 5 ppm を最大濃度として実験を行つた。20日間の実験でFe=1, 3, 5 ppm における増殖量は夫々 5.90 cc/L, 6.20 cc/L, 4.80 cc/L を示し良好であつた。しかしFe=0, 0.1, 0.5 ppm の増殖は著しく悪かつた。

7) Soil extract (Fig. 14)

Soil extract は養鰻池底泥から作つたものである。20日間にわたる実験結果によると，3% Soil extract の添加が最も効果的で 7.60 cc/L を示したが，全体的に見ると 1〜10% の添加は *Microcystis* の増殖に好結果をもたらし，0.5% 以下では効果は著しく小さい。

5. 培養過程における色調の変化と栄養塩添加の効果

Microcystis aeruginosa を培養

している際，最大密度に達して後も，その色調は1ヵ月乃至それ以上にわたつて濃緑色の鮮かな色調を呈するのが通常であるが，殆んど大部分の場合褪色が始まり1週間程で黄褐色に変化するのが観察された。この変化過程は急速に進行する場合が多い。この現象が如何なる原因によつて生ずるのか，また藻種の死滅によるものかを実験するために予察的ではあるが褪色し黄褐色に変化した *Microcystis* に栄養塩を添加，その色調の変化を観察した。藻種は1960年8月15日 subculture を行い，著しく増殖したもので，10月1日から色調に変化を来し，濃緑色から黄褐色になつたものを使用した。

N, P 添加の効果は Table 1 に示した。

N 添加及び N+P 添加では，添加1日後に効果が現れ，細胞は淡緑色になり，2日後には緑色となり，更に3日後には深緑色を呈し褪色前の色調に回復した。一方 P 添加及び，control は実験前と同じく黄褐色を呈していた。従つて黄褐色から鮮緑色への回復は N の添加が即効的であり，またこの実験から黄変した *Microcystis aeruginosa* の細胞は決して死滅したものでないことが分る。

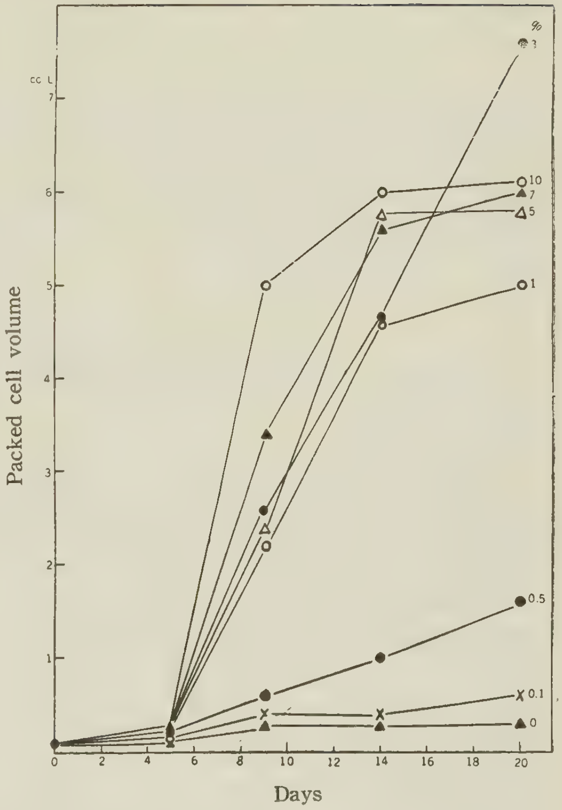

Fig. 14. Growth of *Microcystis aeruginosa* in various concentrations of soil extract.

Table 1. The availability of urea on *Microcystis* cells faded into yellowish brown.
N: NH_2CONH_2 (10 ppm N), P: K_2HPO_4 (5 ppm P).

Treatment	1960. Oct. 10.	Oct. 11.	Oct. 12.	Oct. 13.
Control	Yellowish brown	Yellowish brown	Yellowish brown	Yellowish brown
+N	Yellowish brown	Light green	Green	Deep green
+P	Yellowish brown	Yellowish brown	Yellowish brown	Yellowish brown
N+P	Yellowish brown	Light green	Green	Deep green

6. 要　　約

上述の培養実験の結果を要約すると次のようになる。

1) *Microcystis aeruginosa* の増殖に対する塩分の影響は極めて顕著であり，塩分濃度の増加に伴つて増殖量は著しく減少した。最大は Cl 0.1‰ の淡水にあり，6.00 cc/L を

示した。

2) *Microcystis aeruginosa* の増殖と水温との関係は 20°C～30°C が増殖に適温であり，28°C で最大の 12 cc/L に達した。17°C 以下及び 36°C では殆んど増殖しない。

3) 栄養塩の濃度と *Microcystis aeruginosa* の増殖については夫々，N は 5 ppm，P は 1 ppm，K は 700 ppm，Fe は 3 ppm，Soil extract は 3% の場合の増殖が最もよく，Mg 及び Ca には増殖に対する効果はこの実験からは殆んど認められなかつた。

4) 黄褐色に褪色した *Microcystis aeruginosa* 細胞の緑化には窒素添加が即効的であつた。

IV　考　　察

Microcystis の増殖生理からみた養鰻池

1. 塩　　分

三重県養鰻池における *Microcystis aeruginosa* の分布は池水の塩素量 6‰ を上限とし，その現存量は低鹹池ほど大きく，特に Cl 1‰ 以下の池で卓越する。この結果は，愛知県泉地方の池群における *Microcystis* の分布と塩分との関係[22]とも一致している。このことは純淡水である奈良の金魚池における主要種の一つとして重要視されていること[31]，更に培養実験によつて淡水での増殖量が大きく，塩分濃度の増加に伴い増殖量に顕著な低下が観察されたことによつて裏付けられる。

Microcystis の季節的消長，年次変化などは複雑な池水条件，プランクトン相互の関係などに支配されるであらうが，特に池水の塩分の変動に影響される場合が多い。即ち 1955 年の O_2 池のように池水の塩分が高いために植物プランクトン相は高鹹養鰻池の代表的な種類である藍藻類の *Chroococcus dispersus*, *Merismopedia tenuissima* などが卓越し，*Microcystis* は出現しないが[13]，このことが 1956 年の *Microcystis* の出現の時期，量などに影響しているようである。また 1959 年度の S 池の *Microcystis* は 5 月初旬に出現し，その後著しく増殖して優占種をなしたことは，池水の塩分が前年度より幾分低鹹であることと相俟つて，前年度に *Microcystis* が可成り増殖したことにも起因すると考えられる。

また *Microcystis* の増殖適温期であつても海水注入などの原因によつて塩分が急激に高くなると消滅，あるいは衰退することがある。勿論この場合には池水の高鹹化の程度によつて消滅，衰退の度合は異なり，一時的に消滅しても適温であれば池水の塩分が低くなることによつて再び出現，増殖する。

2. 水　　温

Microcystis の盛衰は基本的には水温の高低と一致し 20°C 以上で増殖が盛んになり，17°C から水温の低下に伴つて次第に衰退，冬期に死滅することが報告されている[18]。

三重県養鰻池の 9 面についての調査結果は凡て 20°C 以上で出現しているが，このような野外調査の結果は培養実験による増殖適温が 20～30°C であるとの結論と一致する。

しかしながら実際の養鰻池においては *Microcystis* にとつて好適の水温条件に達しても，その出現時期は池によつて異なり，水温が 30°C に達する盛夏に出現する場合もある。一方衰退，消滅の時期も前述のように池水の塩分の変化量が *Microcystis* の増殖を抑制する程の高鹹になつた場合は盛夏であつても衰退，消滅が急速に進むが，そうでない場

合は 10 月下旬乃至 12 月中旬まで持続し，水温の低下に伴つて次第に消滅し，急激に消滅することはない。

3. 栄 養 塩

Microcystis の増殖と栄養塩の関係については N=5 ppm，P=1 ppm での増殖量が最大であつた。Gerloff[4] らは N=6.8 ppm，P=1.8 ppm での増殖が著しいことを実験的に明らかにし，N は 1/2 濃度にしても増殖量が低下するが P は 1/10 濃度までは大差のないことを報告し，また更に Michigan 湖での *Microcystis* の増殖の制限要因として N をあげ N/P 比が 60 という N の要求量の大きいことを報告している[6]。このことは筆者が培養実験の際観察した *Microcystis* の色調の変化が N のみの添加によつて急速に緑色に回復する事実などからも N の要求量が大きいことが察せられる。

養鰻池における栄養塩類の含有量，並にその季節的変化については継続的調査に乏しく，唯稲葉による養鰻池の「水変り」前後の栄養塩の変化についての報告があり，水変り後に栄養塩類が著しく増加することを述べている[9]。筆者らは 1955 年，1956 年の 2 カ年にわたり津市江戸橋地区の養鰻池群の栄養塩の季節的変化について調査を行つたが，その結果によると「水変り」を境として池水の栄養塩，特に N，P は著しく増加の傾向を示し，NH_4–N は 3〜5 ppm，PO_4–P は 0.5〜1 ppm の値はしばしば測定された（伊藤・岩井: 未発表)。このことは「水変り」時の水質の変化についての実験的研究結果とも一致している[11]。更に養鰻池においては給餌を通じ多量の有機物が添加されることによつて池水の栄養度は可成り高い。

Microcystis aeruginosa の培養実験による増殖量が前述の栄養塩濃度で 6 cc/L〜7 cc/L という値が得られるが，養鰻池で用いる透明度（直径 5 cm の白色透明度板）で表すと 3 cm に相当し，実際の養鰻池の *Microcystis* を含む植物プランクトンの密度とは比較にならぬ程高い密度である。このように培養実験の結果と，実際の養鰻池での栄養塩の含有量，季節的変化の実態から考えて水温 20°C 以上の *Microcystis* の増殖適温期においては *Microcystis* の消長を支配する要因として栄養塩以上に池水の塩分の影響が大きく，また *Microcystis* の出現期，出現量は前年度における現存量に支配されると考えられる。

4. 池水管理について

集約養魚の形態をとる現在の止水式ウナギ養殖では植物プランクトンによる酸素の供給並に有害物質の除去は不可欠の要素である。*Microcystis* は池水の酸素供給源として最もすぐれ，またウナギの摂餌，収量もよく[10,20]，更に動物プランクトンの異常増殖とその植物プランクトンの捕食作用による「水変り」に対しては *Microcystis* はその捕食限界以上の大きさにあり，「水変り」を軽減するはたらきをもつている[12]。

このような特性をもつた *Microcystis* は養鰻池において最も好ましい重要な植物プランクトンであるといえよう。

前述したように，養鰻池における *Microcystis* の制限要因としては塩分が最も重要であり，低鹹養鰻池，特に Cl 1‰ 以下で卓越し，塩分濃度の増加によつて増殖が著しく低下する。また低鹹養鰻池の植物プランクトンの粒子組成は大型のものが卓越し[24]，その種類相も豊富であること[15]などから，*Microcystis* の増殖をはかるには池水の塩分を Cl 1‰ 以下に保ち，更に増殖期に塩分を高くしないように池水の管理をすることが先づ肝要である。これは池の安定性を高めることにもなるだらう。

V 摘　　要

1. 三重県養鰻池の *Microcystis aeruginosa* の分布と塩分との関係についての野外調査，並に *Microcystis aeruginosa* の分離·培養によつて，その増殖に及ぼす塩分，水温，栄養塩類についての実験的研究を行つた。

2. *Microcystis aeruginosa* の塩分に対する分布上限は Cl 6‰ であり，Cl 1‰ 以下の低鹹養鰻池に特に卓越する。

3. *Microcystis aeruginosa* の増殖に及ぼす塩分の影響についての実験結果は Cl 0.1‰ での増殖量が最も大きく，塩分濃度の増加に伴つて増殖量は著しく低下し，塩分に対する耐忍の巾が狭い。この傾向は野外調査の結果と一致する。

4. *Microcystis aeruginosa* の増殖適温は 20～30°C である。しかしながら出現，消滅の時期は増殖に適する水温範囲であつても夫々の池水条件によつて異る。

5. *Microcystis aeruginosa* の増殖に適する栄養塩濃度は夫々 N は 5 ppm, P は 1ppm, K は 700 乃至 1500 ppm, Fe は 3 ppm, Soil extract は 3% であり，Ca, Mg は濃度差による増殖量に著しい差異は見られなかつた。

6. *Microcystis aeruginosa* の増殖の制限要因としては養鰻池の場合は栄養塩以上に池水の塩分が重要である。

7. *Microcystis aeruginosa* の増殖をはかるには池水の塩分を Cl 1‰ 以下に保ち，塩分を高くしないようにすることが肝要である。

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